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NAVAL POSTGRADUATE SCHOOL

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MARITIME DEFENSE AND SECURITY RESEARCH PROGRAM
FINAL REPORT, 2004-2011

by

CAPT Jeffrey E. Kline, USN (Ret.), Director
and Lyla Englehorn, Research Associate

November 2011

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Prepared for: Assistant Secretary of Defense for Homeland Defense and America's Security Affairs

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NAVAL POSTGRADUATE SCHOOL

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Daniel T. Oliver
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This report was prepared by:

Jeffrey E. Kline
MDSRP Director

Lyla A. Englehorn
Research Associate

Reviewed by:

Dan Boger
National Security Institute Director

Released by:

Karl A. van Bibber, Ph.D.
Vice President and Dean of Research

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and Lyla Englehorn, MPP

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The Maritime Defense and Security Research Program (MDSRP) was part of the National Security Institute (NSI) — a cooperative research institute whose members include the Naval Postgraduate School (NPS), University of California at Santa Barbara (UCSB), and Lawrence Livermore National Laboratory (LLNL). The purpose of the MDSRP was to conduct, coordinate and foster collaboration in maritime defense and security research, experimentation, and information exchange between partnership universities; federal, state, and local agencies; national laboratories; maritime industry, and international partners through the NSI. This report summarizes the program goals, activities and accomplishments from its creation in 2004 to the close of the funding line at the end of fiscal year 2011.

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Final Report, 2004-2011

Edited by CAPT Jeffrey E. Kline, USN (Ret.), Director
Maritime Defense and Security Research Program
and compiled by Lyla Englehorn, Research Associate

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ABSTRACT

The Maritime Defense and Security Research Program (MDSRP) was part of the National Security Institute (NSI) — a cooperative research institute whose members include the Naval Postgraduate School (NPS), University of California at Santa Barbara (UCSB), and Lawrence Livermore National Laboratory (LLNL). The purpose of the MDSRP was to conduct, coordinate and foster collaboration in maritime defense and security research, experimentation, and information exchange between partnership universities; federal, state, and local agencies; national laboratories; maritime industry, and international partners through the NSI. This report summarizes the program goals, activities and accomplishments from its creation in 2004 to the close of the funding line at the end of fiscal year 2011.

KEYWORDS: maritime security, maritime infrastructure, maritime domain awareness, maritime defense and security

POC: CAPT Jeffrey Kline, USN (ret.)
Senior Lecturer
Operations Research
jekline@nps.edu
831-656-7946

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LIST OF ACRONYMS AND ABBREVIATIONS

ADEPT	Atmospheric Detection Effects Prediction Tool
AMSC	Area Maritime Security Committee
ASD(HD)	Assistant Secretary of Defense for Homeland Defense
ASD(NII)	Assistant Secretary of Defense for Networks and Information Integration
ASN(RDT&E)	Assistant Secretary of the Navy – Research, Development, Testing & Evaluation
ASW	Anti-submarine warfare
BDA	Battle damage assessment
BFC	Biometrics Fusion Center
BPR	Business process re-engineering
C2	Command and control
C4I	Command, control, computing, communication, and intelligence
CBP	Customs and Border Protection
CDTEMS	Center for Defense Technology and Education for Military Service
CIA	Central Intelligence Agency
CIP	Critical infrastructure protection
CN	Counter-narcotics missions
CNA	Center for Naval Analyses
CNO	Chief of Naval Operations
COAMPS	Coupled Atmosphere Ocean Mesoscale Prediction System
COASTS	Coalition Operating Area Surveillance and Targeting System
COIN	Counter-insurgency operations
COMFORSUB	Command of the Italian Submarine Forces, Italy
COMPACFLT	Commander U.S. Pacific Fleet

CONOPS	Concept of Operations
COS	Chief of Staff
COTP	Captain of the Port, USCG
COTS	Consumer off-the-shelf
CSDS12	Submarine Development Squadron 12
CSUMB	California State University, Monterey Bay
C-TPAT	Customs-Trade Partnership against Terrorism
DHS	Department of Homeland Security
DIA	Defense Intelligence Agency
DISE	Distributed Information Systems Experimentation
DNI	Director of Naval Intelligence
DoD	Department of Defense
DOT	Department of Transportation
DOTMLPF	Doctrine, organization, training, materiel, leadership and education, personnel and facilities, DoD
DTSA	Defence Science and Technology Agency, Singapore
DTSO	Defense Science and Technology Office, Thailand
EM	Electro-magnetic
EMIO	Extended Maritime Interdiction Operation
EO	Electro-optical
EPIC	Electronic Privacy Information Center
ESM	Electronic surveillance measures
FEX	Field experiment
FIRE	FORCEnet Innovation Research Enterprise
FIST	Field Information Support Tool

FLAK	Fly-Away Kit (COASTS)
FOUO	For Official Use Only
FNMOC	Fleet Numerical Meteorology and Oceanography Center
FSO	Facility Security Officer
GMAII	Global Maritime and Air Integration Initiative, ODNI
GSEAS	Graduate School of Engineering and Applied Sciences
GWOT	Global War on Terror
HA/DR	Humanitarian assistance and disaster response
HFN	Hastily Formed Network
HLD	Homeland Defense
HLS	Homeland Security
HLS/D	Homeland Security and Defense
HSROV	Hull search remotely operated vehicle
I-MPA	International Masters in Public Administration
IC	Intelligence community
ICC	Intelligence Coordination Center
IED	Improvised explosive device
IHPC	Institute for High Performance Computing, Singapore
IMET	International Military Education and Training
IMO	International Maritime Organization
INTs	Integrated navigation and tactical systems
IOC	Interagency Operations Center
IR	Infrared
IS	Information science
JAC	Joint Analysis Center

JAG	Judge Advocate General
JBAIIC	Joint Battlespace Awareness ISR Integration Capability
JCATS	Joint Conflict and Tactical Simulation
JCIDS	Joint Capabilities Integration and Development System
JI	Joint Interagency
JIATF-S	Joint Interagency Task Force-South
JIATF-W	Joint Interagency Task Force-West
JIIB	Joint Intelligence Interoperability Board
JMMES	Joint Multi-Mission Electro-optical System
JSAF	Joint Semi-Autonomous Forces
JSBA	JIIB System Baseline Assessment
LLNL	Lawrence Livermore National Laboratory
LOS	Line of sight
LPR	License plate recognition
LTA	Lighter than air
MARAD	Maritime Administration (DOT)
MARFORPAC	U.S. Marine Forces Pacific
MDA	Maritime Domain Awareness
MDP	Maritime Domain Protection
MDP-RG	Maritime Domain Protection Research Group
MDP-TF	Maritime Domain Protection Task Force
MDSRP	Maritime Defense and Security Research Program
MEC	MARFORPAC Experimentation Center
METOC	Meteorology and oceanography data
MHLS/D	Maritime Homeland Security and Defense

MHS	Maritime Homeland Security
MIED	Maritime improvised explosive device
MIFC	Maritime Intelligence Fusion Center
MIFC LANT	Maritime Intelligence Fusion Center, Atlantic Region
MIIS	Monterey Institute of International Studies, Middlebury College
MINDEF	Ministry of Defence, Singapore
MIO	Maritime Interdiction Operation
MISRAD	Maritime ISR and Detection
MIST	Maritime Information Sharing Taskforce (*now the Multimodal Information Sharing Team*)
MMOWGLI	Massively Multiplayer Online War Game Leveraging the Internet
MOTR	Maritime Operational Threat Response
MPP	Master of Public Policy
MS	Master of Science degree
MSPP	Multi-Sensor Performance Prediction
MTS	Maritime transportation system
MUA	Military Utility Assessment
NATO	North Atlantic Treaty Organization
NAVSEA	Naval Sea Systems Command
NMIC	National Maritime Intelligence Center
NOAA	National Oceanographic and Atmospheric Administration
NOFORN	No foreign nationals, *usually accompanies Secret classification*
NORTHCOM	U.S. Northern Command area of operation
NPS	Naval Postgraduate School
NRO	National Reconnaissance Office

NRP	National Response and Preparedness
NSA	National Security Agency
NSI	National Security Institute
NTA	Nanyang Technical University, Singapore
NUS	National University of Singapore
ODNI	Office of the Director of National Intelligence
OHS	Office of Homeland Security, California
ONI	Office of Naval Intelligence
ONR	Office of Naval Research
OODA	"observe, orient, decide, act"
OPNAV	Office of the Chief of Naval Operations
OSD-ATL	Office of the Secretary of Defense – Acquisitions, Technology & Logistics
PACOM	U.S. Pacific Command area of operation
PAD	People's Alliance for Democracy, Thailand
PANYNJ	Port Authority of New York and New Jersey
PDM	Program Decision Memorandum
PEO C4I	Program Executive Office for C4I
RCT	Requirements, capabilities, and technology
RFID	Radio frequency identification
ROEs	Rules of Engagement
RPG	Rocket-propelled grenade
RTAF	Royal Thai Air Force
RTArF	Royal Thai Armed Forces
RTN	Royal Thai Navy
SAROPS	Search and Rescue Operations Planning Software

SE&I	Systems Engineering & Integration
SEA	NPS Systems Engineering Analysis integrated student project team
SIGINT	Signals intelligence
SNWC	Swedish Naval Warfare Center
SOF	Special Operations Force
SOPAC	Special Operations Command, Pacific
SoS	System of systems
SOUTHCOM	U.S. Southern Command area of operation
SPAWAR	Space and Naval Warfare Systems Command
SSG	Strategic Studies Group, CNO
STRATCOM	U.S. Strategic Command
SUTD	Singapore University of Technology and Design
TDAs	Tactical decision aides
TDSI	Temasek Defence Systems Institute, Singapore
TENCAP	Tactical Exploitation of National Capabilities Program, USN
TNT	Tactical Network Topology
TPED	Tasking, processing, exploitation, and dissemination
TTPs	Tactics, Techniques and Procedures
TVA	Threat and Vulnerability Assessment
TW	Trident Warrior
TW/SH	Trident Warrior/Silent Hammer
UAV	Unmanned aerial vehicle
UCSB	University of California, Santa Barbara
UGV	Unmanned ground vehicle
UoB	University of Bundeswhr, Munich

USCG	U.S. Coast Guard
USCG/R&DC	USCG Research and Development Center
USN	U.S. Navy
USNORTHCOM	U.S. Northern Command
USPACOM	U.S. Pacific Command
USSOCOM	U.S. Special Operations Command
USSOUTHCOM	U.S. Southern Command
USV	Unmanned surface vehicle
USW	Undersea Warfare
UUV	Unmanned underwater vehicle
UxS	Unmanned systems
VBIED	Vehicle borne improvised explosive device
VOI	Vessels of interest

EXECUTIVE SUMMARY

"To dissuade and defeat threats as early and as far from U.S. borders as possible."

Program Objective: Through the National Security Institute, conduct, coordinate and collaborate maritime defense and security research, experimentation, and information exchange between partnership universities; federal, state, and local agencies; national laboratories; the maritime industry, and international partners.

The Maritime Defense and Security Research program (MDSRP) was part of the National Security Institute (NSI) — a cooperative research institute whose members include the Naval Postgraduate School (NPS), University of California at Santa Barbara (UCSB), and Lawrence Livermore National Laboratory (LLNL). The purpose of the MDSRP was to conduct, coordinate and collaborate maritime defense and security research, experimentation, and information exchange between partnership universities; federal, state, and local agencies; national laboratories; maritime industry, and international partners through the NSI. During its seven year operating period, the MDSRP created a community of interest with over one thousand members; inspired interagency cooperation through meetings, symposia, and short education programs; motivated interdisciplinary research and experimentation in maritime domain awareness, national maritime policy, and counter-piracy; and created a venue for government, industry, and academia to address maritime security issues.

In collaboration with other sponsors, the MDSRP also underwrote several major field experimentations at NPS including the maritime interdiction experimentation by Tactical Network Topology (TNT), the Coalition Operating Area Surveillance and Targeting System (COASTS) and the Seaweb system of networked underwater sensors. Other programs receiving MDSRP funding include the NPS Graduate School of Engineering and Applied Sciences (GSEAS) maritime domain awareness (MDA) work and environmental impact on sensors. The MDSRP also gave initial funding to the Maritime Information Sharing Task Force (MIST) which, co-sponsored with the U.S. Department of Transportation (DOT), continues to hold

workshops in several U.S. domestic regional ports to research policy barriers to information exchange between commercial entities and government agencies. Additionally, MDSRP supported faculty labor and travel to attend various Maritime Homeland Defense and Security conferences or host them at NPS. Finally, MDSRP support allowed NPS to publish and distribute the monthly SITREP e-newsletter which reported national research initiatives related to maritime security to an international level distribution list.

ACKNOWLEDGMENTS

This report represents a compilation and summary of the work of a multitude of researchers, scientists, academicians, students, and warfighters. A generous thanks is extended to all those whose work contributed to the success of the Maritime Defense and Security Research Program (MDSRP).

The MDSRP also wishes to thank all those that keep our nation safe.

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I. ORIGINS AND BACKGROUND

FOUNDING MISSION STATEMENT: *use the warfighter's perspective to detect, dissuade and defeat maritime threats and aggression against the U.S. and its citizens.*

The Maritime Defense and Security Research Program (MDSRP) was designed as an umbrella initiative to coordinate and execute various maritime defense and security exercise, research, and education programs at the Naval Postgraduate School (NPS) and with other academic, interagency, government, industry and international organizations. These programs included systems research into the political, organizational, technical, and physical aspects of MDA, response, and port security; direct support to the Navy's maritime domain awareness (MDA) research and experimentation spiral; short courses in maritime interagency planning; red cell activities associated with maritime counter-terrorism and counter-piracy; and field experimentation work. Students were integrated in all aspects of these programs providing them "hands on" experience in solving relevant operational issues that could then be applied throughout their career while establishing life-long interagency and international contacts. The MDSRP also supported a classified repository of knowledge and documents concerning MDA and maritime defense and security issues at the NPS Dudley Knox Library for government agencies and researchers.

A. BEGINNINGS

In early December 2003, NPS was tapped by the Office of the Assistant Secretary for Homeland Defense to form a research and investigative task force to address issues surrounding the protection of the U.S., its vessels, and citizens against threats originating in the maritime domain. Leveraging funds provided by Congress for research to affect military operations called the Center for Defense Technology and Education for Military Service (CDTEMS), the NPS Maritime Domain Protection Task Force (MDP-TF) was formed in response to Assistant Secretary of Defense for Homeland Defense (ASD(HD)) McHale's request to provide his staff insight in various areas concerning protection from maritime terrorist threats. Organizational efforts began in January 2004, and within a

month included over twenty-five faculty and fifteen students proposing research in the following areas:

- Vulnerability and threat assessment
- Systems architecture and integration
    - Interagency command and control (C2) in the maritime domain
    - Layered concept of operations (CONOPS) for maritime homeland defense
- Maritime domain awareness
    - Data tagging and fusion
    - Systems design and multi-level security
    - Intelligence collection and dissemination
- Port security and infrastructure
- Mid-ocean real-time local environmental predictions to aid in intercept operations
- Secure archiving of research information in the maritime domain
- Creation of a Maritime Domain Protection Lab and Wargaming facility

As of March 2004, over fifty NPS faculty, students and staff had aligned their research with this new venture, complimenting established research areas. In addition to on-campus resources, the MDP-TF created over sixty points of contact from various DoD and federal agencies concerned with MDA; C2; and operations to detect, deter, defeat, or nullify terrorism in the maritime domain.

Within the first few years of operations the MDP-TF evolved into the Maritime Domain Protection Research Group (MDP-RG) at the behest of the NPS Board of Advisors, however per guidance from the ASD(HD) maintained the goal of defeating and dissuading threats originating in the maritime domain.

In its first fifteen months of operation the MDP-RG was formed, research efforts progressed significantly, and interest more than tripled. The MDP-RG served as an umbrella for many different research initiatives, ranging from conducting threat

assessments to developing MDA technology to designing a systems engineering architecture for MDP. Together, these initiatives provide essential input to the national MDP effort and will assist in the development of a more complete and effective MDP system. In just under a year and a half, the MDP-RG's accomplishments included:

- Published an "AS IS" description of the current national MDP system
- Conducted classified intelligence, strategy, and technical seminars to bring different federal agencies together to meet and explore solutions to common objectives
- Created a Maritime Domain Protection Wargame facility capable of classified and non-classified CONOPS analysis
- Proposed an systems architecture for use of Biometrics for civilian merchant crews
- Participated in national level MDA efforts including reviewing draft national guidance
- Created a community of MDP stakeholders, drawn from industry, national labs, government agencies, and local officials
- Assisted in establishing a Homeland Security Digital Library at NPS
- Supported local law enforcement through internship opportunities

A neutral facilitator between the many Department of Defense and other governmental agencies interested in Homeland Security (HLS) and Homeland Defense (HLD), the MDP-RG successfully brought together engineers, scientists, law enforcement, military, government, contractors, and NPS faculty, staff, and students – each bringing a unique perspective and expertise to the issue of maritime domain protection.

1. Filling a Gap

The ASD(HD) leveraged NPS to define, design, and potentially implement a national maritime domain protection (MDP) system that included a vulnerability

assessment, concept of operations across multiple lines of defense and domains, and was coordinated through a national command and control system. Looking at MDP from the warfighter's perspective, the group focused on how to dissuade, deter, preempt, interdict, or defeat threats and aggression as early and as far from U.S. borders as possible.

The combination of a diverse and talented faculty with background in interdisciplinary approach to DoD problems, a secure research environment, and operationally experienced students from DoD and the U.S. Department of Homeland Security (DHS) focused on applying graduate education towards national complex issues made NPS the ideal home for this effort. Additionally, the lack of institutional bias and potential as a base for long-term efforts due to low faculty turn-over rates added to the appeal.

2. Initial Goals

The MDSRP was formed to investigate issues surrounding protection of the U.S., its vessels, and citizens from terrorist threats originating in the maritime domain. The initial stated goal of the group was to coordinate, research and investigate issues involving the DoD's responsibilities and roles in Homeland Defense. Stakeholders included a variety of agencies and offices throughout the U.S. and several international allies. In the first few years of existence, the MDSRP explored methods to define, design, and aid the implementation of a national MDP system to assist in defeating maritime terrorism as early and as far from U.S. borders as possible.

Near term goals identified to be addressed in the first eight to fifteen months of the program launch were:

- To complete an initial vulnerability assessment
- To produce an "AS IS" system architecture description
- To produce a needs and requirements document
- To build a Maritime Domain Protection Modeling and Gaming Laboratory
- To coordinate MDA research across NPS campus-wide efforts; and

- To cross communicate within a developing community of interest

B. THE PLAN

The midterm program goals to be addressed in the first three years were to:

- Draft proposed *National Maritime Domain Protection Architecture* articulating CONOPS and command structure, then test this proposal in interagency/joint war game
- Develop an MDP Library database for classified interagency reference
- Begin port infrastructure analysis in relation to support of U.S. force projection
- Extend current data mining and fusion techniques and systems based on requirements generation

The long term program goals projected out five years were to:

- Refine and implement national MDP CONOPS
- Continue use of MDP lab and wargaming facility to test Unified Command Maritime CONOPS
- Complete port infrastructure analysis in relation to support of U.S. force projection, begun in the mid term
- Develop automatic data mining and fusion systems for multi-level security access
- Evaluate alternative platform capabilities for MDP

1. Building a Collaborative Community

The 9/11 Commission identified maritime ports as a major vulnerability point for our nation. An early identified need was to have a symbol to unify the diverse group of stakeholders involved in MDP. Members of the MDSRP created a logo representing the goals and aspirations of the task at hand:

- **Shield:** Represents Protection
- **Stripes:** Represent American Strength
- **Stars:** Represent Patriotism
- **Anchor:** Represents the Maritime Domain
- **Olive Branches:** Represent Peace

Many diverse members of this "club" still wear the MDSRP logo as a lapel pin symbolizing their dedication to the tenets of MDP.

a. SITREP

To meet the growing request for information sharing amongst geographically diverse stakeholders, an early MDSRP effort was to produce and distribute a monthly e-news brief covering the spectrum of maritime domain defense and security research. Called the SITREP to represent the foundational mandate to establish a current "situation report" of disparate MDP efforts, the first issue was released in February 2004. Each issue of the SITREP introduced on-going maritime security research projects at NPS, from the National Security Institute, or other research institutions or agencies working in MDP. Since its first issue, the SITREP has been sent to an ever growing list of stakeholders ranging from academics, researchers and scientists; to warfighters and military strategists; to policy analysts and decision makers worldwide.

The final issue of the SITREP, volume 56, will be released in December 2011 and will be sent to a distribution list of over 1,200 MDP stakeholders.

b. Monthly meetings

Since 2004, the MDSRP has hosted monthly meetings on the NPS campus to showcase current projects and facilitate a "round robin" to allow current MDSRP members to update the full group on the status of their work. Off campus partners have participated regularly using either voice or video conference technology available in several locations on campus. In his most recent book *Where Good Ideas Come From: the natural history of innovation*, cultural commentator and popular science writer Steven Johnson cites the work of Kevin Dunbar of McGill University that found the most conducive environment for research innovation was not the lab but the conference table in the form of monthly meetings. Dunbar wrote, "the results of one person's reasoning became the input to another person's reasoning…resulting in significant changes in all aspects of the way the research was conducted (quoted by Johnson, 2010)."

2. Research and Thesis Opportunities

With the MDSRP in residence at NPS, a program function was always to foster the continuing education of resident and non-resident NPS students. All NPS students must complete a thesis or major projects as part of their degree program, and potential research topics related to MDP were proposed as an early effort of the new MDSRP. Some examples from this initial detailed list produced in 2005 were:

1) The idea/feasibility of a Multinational Joint Fusion Center focused on Caribbean Basin issue – i.e. either a separate center based in another country and/or foreign liaison officers added to Maritime Intelligence Fusion Center, Atlantic Region (MIFC LANT) much like Joint Interagency Task Force, South (JIATF-S) does.

2) Organizational topics: Identify "lanes in the road" for the National Maritime Intelligence Center (NMIC) and the MIFCs? Could also look at the U.S. Coast Guard's (USCG's) Intelligence Coordination Center (ICC) or ICC vis-à-vis. area/district intelligence staffs.

3) Identify respective roles for USCG intelligence personnel and U.S. Navy (USN) intelligence in homeland security?

4) Issues of intelligence sharing and corruption among Latin American partners on the war on drugs/ terrorism. Is it wise to entrust our intelligence methods and information to these highly volatile governments?

5) Sharing law enforcement information: overcoming obstacles in the beltway.

6) Identify/assess some national technical capabilities that will be needed to attain MDA (drones, sensors, integrated navigation and tactical systems (INTs), etc…).

7) Identify the roles of the local, state, and federal government and the private owners and operators of critical infrastructure in Maritime Homeland Security.

8) Improving the security of the cargo supply chain without hindering the free movement of legitimate cargo.

These thesis topic areas were later consolidated and refined as follows:

- Vulnerability assessments
- National C2 structure
- International waters *Intercept and Defeat* CONOPS development
- Shipping and container industry initiatives and cooperation opportunities
- Data mining, storage, and fusion
- Port infrastructure
- Allied opportunities

At the close of FY11 over 150 student theses and projects had been completed with MDSRP support. This support was in the form of funded faculty serving as thesis advisors, mentors, and readers; or direct funding for individual student research activities. A representative listing of MDSRP supported student theses is included as an appendix to this report (*see Appendix D*).

3. Seed Money

MDSRP funding from Navy accounts was $1.0M per year through FY11. This was provided as a DoD Program Decision Memorandum (PDM) in the 2006 Defense Program. Separate research dollars from various sponsors and research collaborators were also leveraged to inspire program success.

Anticipating this resource allocation on the federal level, MDSRP funding was always envisioned as seed money to get new programs off the ground, not as a primary funding source for continuing work on established projects. A prime example is the Maritime Information Sharing Taskforce (MIST) (*see section II:A:17*). Originally conceived as a joint project between NPS and the Department of Transportation's (DOT's) Maritime Administration (MARAD), the prototype MIST event held in the combined Ports of Los Angeles and Long Beach was fully funded by MDSRP. The next two MIST events were only partially funded by MDSRP, with other federal level sponsors providing resources. The fourth MIST event in Philadelphia in 2010 was fully funded outside the auspices of the MDSRP. The MIST Boston process, with a research event in September 2011, was again sponsored fully beyond MDSRP. Without initial seed money, this important research project would not have gotten off the "white paper" proposal stage. But after maturation, the program has realized its full potential and is able to solicit funding on its own.

With the close of the MDSRP, many supported projects and programs detailed in this report will continue to evolve with alternate funding sources – several of these are cited in the closing section (*see section III:B*). However, without the initial MDSRP seed money, many of these same programs would have never gotten started.

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II. PROGRAM REVIEW

The NPS National Security Institute's MDSRP was an inclusive multidisciplinary program that supported the research of over forty NPS faculty and their students in partnership with a variety of off-campus members from multiple agencies, national labs, industry and academia (*see Appendix E*). These programs included various research projects to develop maritime operational planning aids, red teaming projects, and education programs; various maritime awareness initiatives from multilevel security to barriers to information exchange with industry; and an extensive field experimentation program that explores the latest technology in unmanned systems (UxS), mobile C2 capabilities, and reach back data transfer and monitoring. Over the course of eight years, the MDSRP provided seed money for over twenty programs and projects, and served as a partner as projects evolved. These programs fell into three major areas:

- Research
- Education (including symposia, short courses, and red team activities)
- Experimentation

The MDSRP's multiple initiatives all fell within the following major mission areas:

- Maritime warfare research
- At sea, in port and field experimentation programs
- Exploratory research programs
- Education and red teaming programs

The MDSRP consistently emphasized collaboration with other services, agencies, state and local governments, industry, and allies. A representative listing of partners is included as an appendix to this report (*see Appendix E*). At the close of FY11 the MDSRP leaves several functional projects ready to move to the next step. These include:

- A three course International Maritime Security Certificate program ready to be delivered to a professional student audience
- Emerging research into reinforcing institutional integrity to support maritime regional security
- Modeling of port security systems and their effectiveness
- Risk assessment tools in maritime critical infrastructure protection (CIP) and platforms versus intercepts
- Visualization of data analysis

A. RESEARCH

MDSRP supported research programs ran the gamut as far as subject areas, perspectives and approaches. Leveraging NPS faculty, staff and students with strong academic credentials and significant operational experience, mission areas researched related to UxS threat analysis, USW effectiveness and projects of benefit to maritime operational planners. Some projects that started as research, evolved into experimentation programs. Others informed coursework and became thesis topics. Still others were operationalized on the national level, informing CONOPS and maritime security policy.

1. Systems Engineering and Integration

The goal of the Systems Engineering and Integration (SE&I) Team was to establish an overarching, open architecture for a nationally integrated MDP system that would best support the nation's effort in preventing terrorists from exploiting the world's oceans to attack the U.S., its forces, its force projection capability, and other interests. The multi-year SE&I effort focused on the delivery of a proposed architecture on which to base future process and technical design. This was a collaborative project between several NPS faculty and students from the USN, USCG, U.S. Northern Command (USNORTHCOM), and other MDP project participants from various government agencies.

Using a multilevel architecture engineering process *(see Figure 1)*, the SE&I Team 1) defined the MDP problem, 2) developed an MDP architecture engineering methodology, 3) developed operational and threat scenarios for modeling and testing architectural alternatives, and 4) identified and assessed an "AS-IS" MDP system (document number NPS-097-04-005, *For Official Use Only* (FOUO)). Researchers also performed preliminary functional requirements and initiated a modeling and simulation effort to support architectural design for an MDP system.

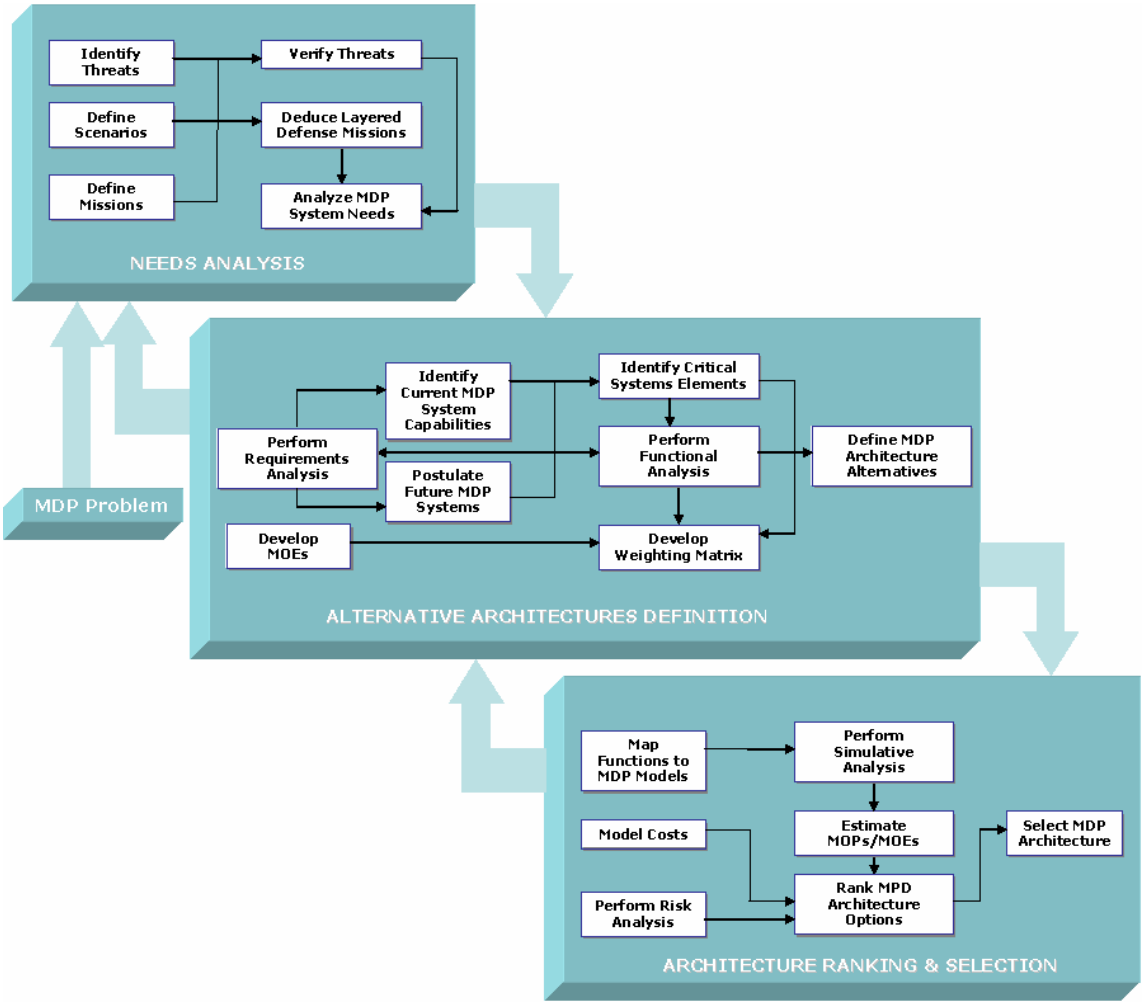

Figure 1. MDP Architecture Engineering Process

SE&I researchers initially concentrated on evaluating current MDP efforts and the myriad of organizations involved in maritime defense. Through a comprehensive review of relevant literature, interviews with vital stakeholders including USNORTHCOM, U.S.

Special Operations Command (USSOCOM), U.S. Pacific Command (USPACOM), USCG, the Office of Naval Intelligence (ONI), U.S. Navy Forces North (NAVNORTH), the National Security Agency (NSA), and the Defense Intelligence Agency (DIA), and participation in MDP conferences and symposia, SE&I researchers compiled an assessment of the current national MDP system capabilities (document number NPS-097-04-005, FOUO).

SE&I faculty team members included Tom Huynh, Orin Marvel, John Osmundson, Gene Paulo, and Mark Stevens.

POCs: Dr. Tom Huynh (thuynh@nps.edu) and Professor Mark Stevens (mstevens@nps.edu)

a. SEA-7 Cross Campus Study: Port Security & Malaccan Strait Navigation Safety (Singapore/LLNL)

The SE&I research effort described above evolved to include an NPS cross campus integrated study coordinated by the seventh Systems Engineering Analysis (SEA) cohort students for their graduation capstone project – referred to as the SEA-7 Cross Campus Study. This SEA cross campus study was essentially a systems study requiring international cooperation titled "*Maritime Domain Protection in the Straits of Malacca*," and focused on large ship and port security in the Port of Singapore and the nearby Straits of Malacca. As the topic was well within the MDSRP topic areas of interest, the program offered faculty and funding support to the SEA-7 student team. NPS GSEAS students, in collaboration with students from the Temasek Defense Systems Institute (TDSI) in Singapore, designed and assessed various system-of-systems architecture alternatives for countering threats to and from large ships in the Straits of Malacca, including: sensor suites, communications, C2, and reactive forces for a coalition of nations. The GSEAS team also designed and assessed ship inspection architecture alternatives for detecting explosive and dangerous materials in order to prevent a large cargo ship from being used as a terrorist vehicle. Robotic systems were considered as a component of this ship inspection system. Findings of this study were presented in June 2004 at NPS. The study was also presented to ASD(HD) staff and to an international

audience at the Asian Military Operations Research Symposium in Malaysia at the request of Commander, Pacific Command. A final project report is available upon request (MDP CC4913 Final Report).

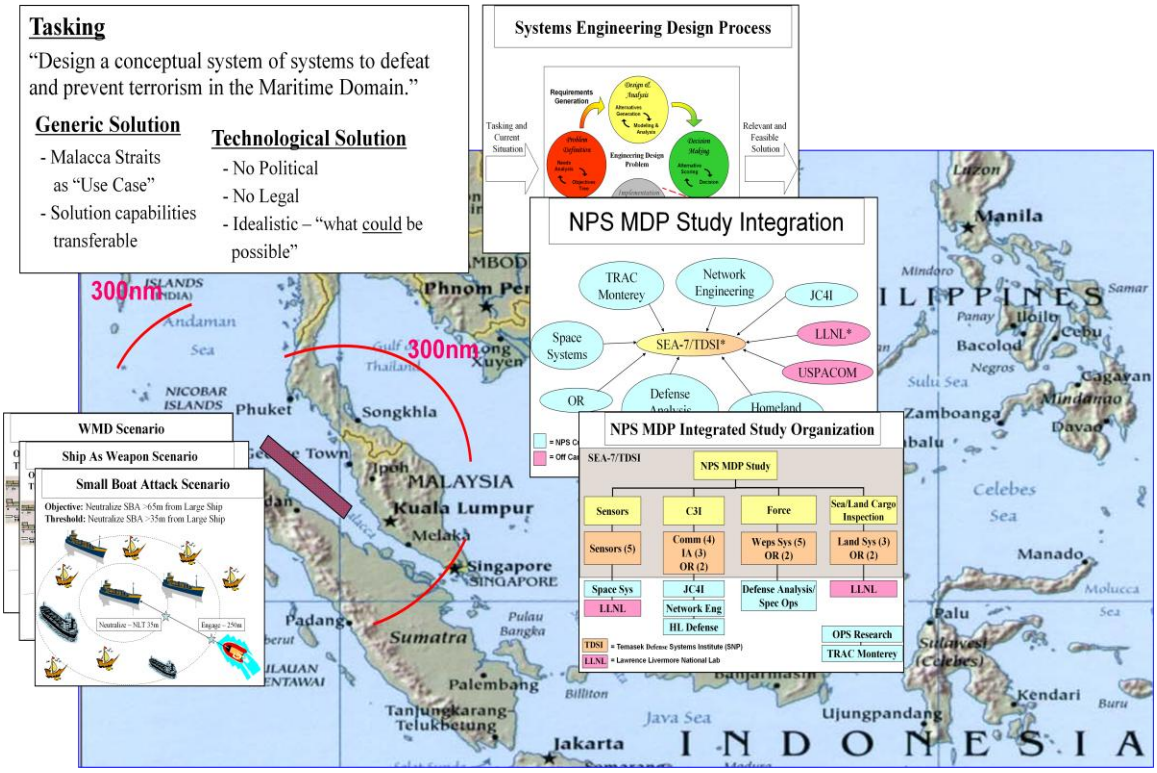

Figure 2. Singapore/LLNL cooperative systems study

The following year, the cross campus study conducted by the eighth cohort of SEA students (SEA-8), *Maritime Domain Protection-Countering Terrorism from the Sea*, also looked at a topic area important to the MDSRP. Faculty expertise and research were offered to assist this group as well. Findings were presented in June 2005 (*see Figure 2*). Subsequent SEA cross campus topics related to the MDSRP included port maritime interception (2006), global fleet stationing (2007), extended maritime interdiction operations (2008), and developing a system of systems that would combat and defeat mines and underwater improvised explosive devices (IEDs) placed in U.S. ports (2009).

SEA cross campus studies continue as an integral part of NPS student interdisciplinary work, and are available for review online. Visit

http://www.nps.edu/Academics/Programs/SEA/subpages/ArchivedProjects.html for more information and links to final presentations and reports.

POCs: Dr. Gene Paulo (eppaulo@nps.edu) and Jeff Kline (jekline@nps.edu)

b. MDP Joint C4I Capstone Study, June 2004

The SE&I research team also supported a student effort to employ the "observe, orient, decide and act" (OODA) framework to develop a MDP C2 architecture. Thirteen students from the NPS Information Science (IS) Department analyzed organizations and commanders, speed of decision and response time latencies, and decision processes and processors – doctrine. Information trade-offs, sensor and communication requirements, rules of engagement (ROEs), and legal requirements and constraints were also part of the student lead study. As a result of their analysis, students proposed an ideal structure for a Joint Interagency Task Force (JIATF) "plus X" organization.

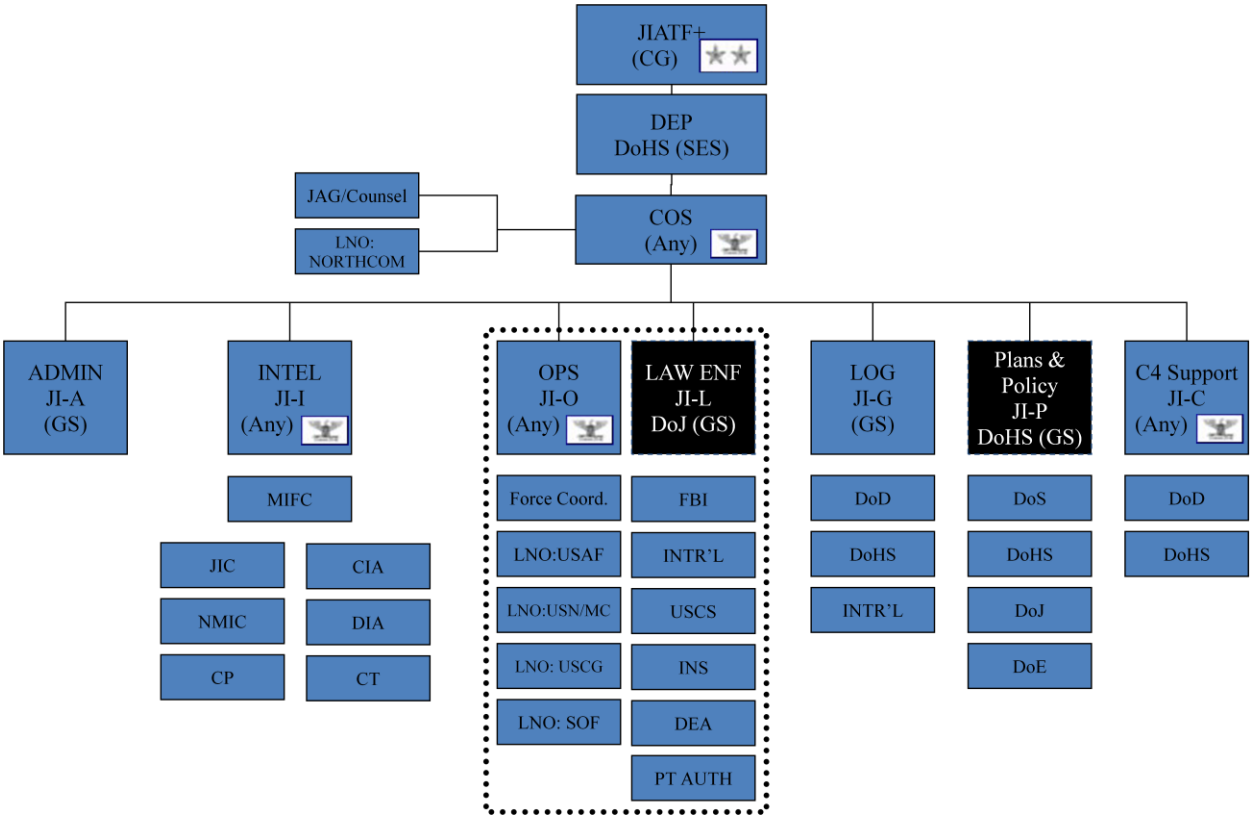

Figure 3. JIATF+ X organizational structure proposed by Joint C4I students

The students presented a proposed organizational structure (*see Figure 3*) to maximize the interactions between civilian and military personnel. The student led team recommended that a USCG Rear Admiral should head the JIATF because the USCG bridges the gap between military action (Title 10) and law enforcement (Title 50). In addition, they recommended that a DHS Security Senior Executive Service civilian be the deputy. The Chief of Staff (COS) would be a uniformed member of any service, supported by a Judge Advocate General (JAG) Officer or legal counsel. The team contended that it would be necessary to keep the legal recommendations separate from intelligence, operations and law enforcement. In addition, USNORTHCOM would have a liaison officer keeping his parent command apprised of any impending actions which they may have to take. To further the integration between the uniform and civilian staff members, they used Joint Interagency (JI) directorates and letter codes, rather than numbers as a traditional military staff might.

This structure has many similarities to standard military command structures. However, the major difference lies in the two added divisions: *Law Enforcement* and *Plans & Policy*. Both would be integral to conducting successful MDP operations because DoD assets will be required to work closely with law enforcement agencies. Additionally, they recommended that the Intelligence Directorate be headed with a Colonel or Captain (USN or USCG) because of the relative importance of MDA to MDP. The *Operations* and *Law Enforcement* directorates will be closely linked for administrative and operational functions. The operations directorate is a fluid division as service components send forces into and out of the operational control of the JIATF+ commander. The Plans and Policy Division would include representatives from State, Homeland Security, Justice and (when needed) Energy departments so that political options can be used instead of military operations or law enforcement actions.

Standard administration, logistics, and C4I (command, control, computing, communication and intelligence) support would be included in the makeup of the architecture. Also fluid in the architecture will be international representation. They will serve as a link to any foreign country's logistical support and law enforcement. The student team emphasized that absolutely necessary to the success of the JIATF+ was the

coordination and integration between the Intelligence Watches (MIFC) and the Operations Watches. All elements of the intelligence, operations, law enforcement and legal agencies were represented.

POC: Dr. Dan Boger (dboger@nps.edu)

2. SEA-13: Maritime Interdiction Operations in Logistically Barren Environs

In January 2008, forty-seven students from the U.S., Singapore, Israel, and Taiwan organized and responded to tasking to develop a system capable of conducting Maritime Interdiction Operations in a logistically barren environment. The purpose was to immerse students in the realities of being a systems engineer to find solutions to complex problems. They set their direction, organized, and identified and integrated other students and faculty from across campus as well as subject experts and stakeholders outside the school. In this project, the students acted as lead systems engineers to conduct a major integrated project on topics relevant to the U.S. Navy and participating stakeholders. They worked in a six month delivery schedule for a final report and briefing in partial fulfillment of their requirements for a Master of Science (MS) degree in Systems Engineering and Analysis (SEA). A key factor in the success of the SEA-13 students was to respond appropriately to the various limitations imposed on maritime operations to satisfy their mission objectives and avoid marooning critically-needed forces in logistically-barren environs.

The SEA-13 final report is available for review at http://www.nps.edu/Academics/Programs/SEA/subpages/projects/2008Spring.html.

POC: Professor Gary Langford (golangfo@nps.edu)

3. Threat and Vulnerability Assessment (TVA) Team

This research was based on two overarching assumptions: 1) incremental academic and scholarly rigor will lead to continued improvement for government policy makers and operational decision makers, resulting in practical application of advances in shared expertise and knowledge; and 2) increased communication at the operational level

will allow for more accurate and timely threat assessments, resulting in shared threat identification and moving us toward elimination of seams in maritime vulnerabilities. The Threat and Vulnerability Assessment (TVA) Team focused on developing and compiling comprehensive threat and vulnerability assessments needed to identify weaknesses, discern the likelihood and intensity of potential dangers, and help focus protection and forward action. Their goal was to identify where to direct assets to minimize threats.

The TVA team's work evolved to include the following definition of risk:

Risk = (Threat + Vulnerability) - Capability

This formula reveals that capabilities can be developed to mitigate risks, even though the threats are still there. Capabilities reduce vulnerability. This risk equation demonstrates that increased understanding of threats eases mitigation efforts. This idea might seem obvious now, but it was not so obvious to the team in 2004. What this formula really demonstrated is that risk can be managed.

Members of the TVA Team were CAPT Steven Ashby, USN, Professors Mitch Brown and Paul Shemella, and NPS students LCDR Robert Hight, LT Mark Steliga, and LT Jay Dewan.

POC: Professor Paul Shemella (pshemell@nps.edu)

a. TVA Symposium, June 2004

In June 2004, the TVA Team energized a growing community of interest by organizing and conducting an initial TVA symposium with a carefully selected group of participants from military, government, and the private sector (*see Figure 4*).

Figure 4. (L to R) Prof. Mitch Brown, NWC, Monterey Campus, and Mr. Frederick Ferrer, Senior Policy Analyst, Office of the ASD (HD) at the TVA Symposium, June 2004

One of the goals of the June symposium was to foster an extensive "network of networks" among government, military, and the private sector, as an initial outreach to stakeholders in maritime domain protection issues. Approximately forty personnel from diverse organizations and fifteen representatives from NPS and the Naval War College shared their time and expertise. The three day event was dedicated to identifying threats and dangers to U.S. security, matching threats to vulnerabilities, improving methods for assessing threats, and envisioning a "future and forward" look at maritime domain awareness. The final portion of the symposium was dedicated to panel-driven and discussion-oriented vignettes, in which conference attendees were broken into two groups and given the task of dealing with several scenarios which threaten U.S. interests in the maritime domain. In their after action report on this event released in September 2004, the TVA Team demonstrated that vulnerability assessments are on-going but rarely tested or generically applied, and the process of matching threats to vulnerabilities is conducted in an "ad hoc" manner. This report is classified SECRET NOFORN.

b. Building TVA "Network-of-Networks"

In 2005, the TVA researchers continued to build and improve this "network of networks" (*see Table 1*) through table-top and lab war gaming techniques to more thoroughly investigate identified and potential threats to existing vulnerabilities, both known and unknown. This research built on the advantages gained from an

increasingly robust threat identification process. Researchers then focused on the more difficult issue of assessing vulnerabilities.

Table 1. TVA Efforts toward Building a "Network of Networks"

RADM Porterfield, Director of Naval Intelligence (DNI):	Addressed Naval Intelligence students on their thesis work.
Admiral Robert Murrett, DNI:	Provided guidance and vision to students working a variety of related theses
CDR Jay Steadman, Senior Intelligence Officer, Naval Criminal Investigative Service, Multiple Threat Alert Center:	Addressed over 20 intelligence officers on MTAC's current threat assessment and procedures they are currently using for assessments
LT David Sanchez, U.S. Southern Command:	Led a seminar discussion on SOUTHCOM's counter-terrorism operations
CAPT Tim Doorey, Joint Chiefs of Staff Crisis Management:	Provided insight on JCS activities regarding the Global War on Terror
Mr. Dave McDonald, U.S. Pacific Command Intelligence Architectures:	Provided briefings and discussions on how horizontal integration can assist the threat and vulnerability assessment process
LT Todd Gleghorn, NPSAlumni:	Provided insight into CNO Intelligence Plot procedures and the impact of open source intelligence on threat assessments
Mr. William Arras, Digital Globe and Mr. Steve Holsinger, OSO:	Provided practical insights on how to better use commercial and national imagery for HLD/HLS.
Mr. Bill Moffet, Central Intelligence Agency, Office of Military Affairs:	Led a seminar detailing how working military and the CIA could better integrate assessments.
LtCol Curt Reidel, AFOSI Liaison Officer, Federal Bureau of Investigation:	Provided students and faculty insight into how counterintelligence is conducted and measures being taken for improvement.
Mini-Symposium with JIATF-W J2 [CAPT Marc Luoma, USN JIATF-W J2 Representative, CDR Robert Dean, USCG and Mr. Shawn James, Lockheed Martin Vice President]:	The symposium covered issues from organization to transnational crime and analytical techniques for improving HLD/HLS.
Student Participation:	Several students attended conferences and conducted research and field work, including visits to imagery and signals intelligence (SIGINT) sites, Air Force TENCAP, USAF Space Command and USNORTHCOM Headquarters, to gain insight into techniques and procedures to improve threat assessments.

4. Applied At-Sea Technology

NPS experience in supporting field tests on radar/infrared (IR) sensor performance suggests that, for port and coastal security, surveillance must consider atmosphere and ocean surface effects. The environmental conditions affecting sensors, the size and speed of targets involved, and the threat procedures important to MDP are very different from ship self-defense against mach-1 surface-skimming missiles. Hence, special integration of models and testing of approaches are necessary.

The goal of the Applied At-Sea Technology research project was to describe the current state of threat and own-force detection capabilities in the national MDP system when including atmosphere and ocean surface conditions which influence radar (refractivity profiles) and IR (thermal contrast, absorption, and aerosol scattering) sensor performance. The project was based on the transition of models and procedures developed for USN sensor performance prediction, to apply in port and coastal surveillance and also in response detection estimations (*see Figure 5*).

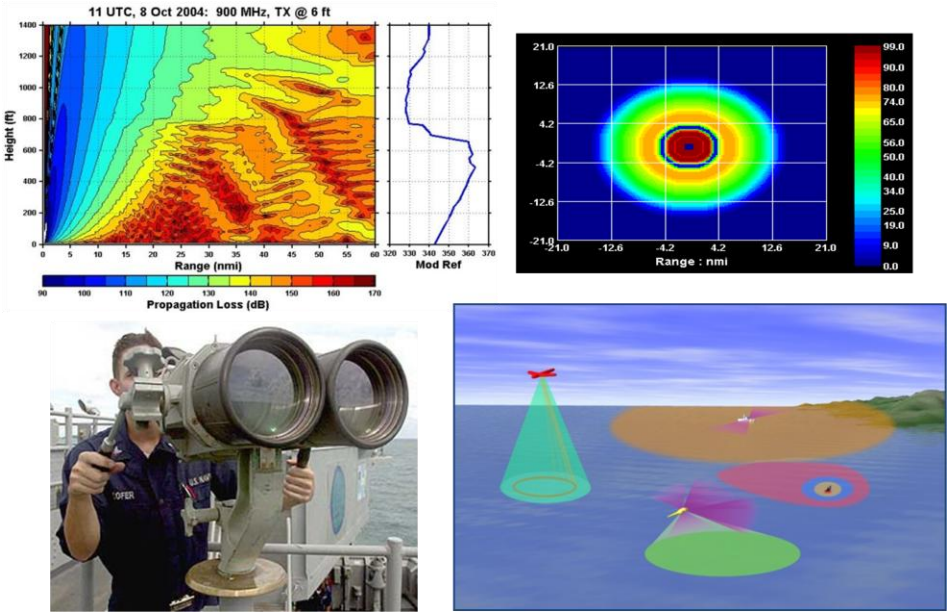

Figure 5. Atmosphere MDA Rf/IR impact

NPS has participated in meteorology and oceanography impact assessments in almost every major optical and radar propagation field test involving the USN over the last decade. MDSRP support enabled special analyses of this data to describe the current

state of MDP. The sampling and analysis methods derived from these tests were applied in a fleet exercise involving low cross-section targets. The approach followed in the Applied At-Sea efforts was similar to that applied previously in collaboration, consultation, collection and interpretation with regard to detection of low cross section surface and submarine mast targets. In fiscal years 2004 and 2005, these applications included:

1) Follow-on analyses for MDP objectives of results from Naval Special Warfare Command directed field tests (2002-2004) on combatant craft detection,
2) Participation in an electronic surveillance measures (ESM) vulnerability study with Submarine Development Squadron 12 (CSDS12) off San Clemente Island, California (July 2004),
3) Participation and analyses of results from the Trident Warrior/Silent Hammer fleet exercise (with sub assets) off San Clemente Island, California (October 2004),
4) Participation in a IR detection field test in San Diego Bay, performed for a Naval Sea Systems Command (NAVSEA) ship self-defense program, on IR detection,
5) Participation in Monterey Bay based USSOCOM demonstrations involving radar/EO surveillance sensors, now occurring,
6) Providing faculty direction and support to students within NPS *Cross-Campus Integrated Study: Maritime Domain Protection in the Straits of Malacca*,
7) Continued participation with NPS MDSRP

The At-Sea Technology Team provided special guidance and support to sensor team students, divided into a radar group and an EO/IR group, working on one of three projects carried out by the SEA-7 students as part of the cross campus integrated study MDP in the Straits of Malacca (*see report section II:A:1:a*). This effort is significant because it focuses MDP on important regions, such as the PACOM area of responsibility, regarding the potential impact of the conditions and procedures for meeting surveillance requirements. SEA-7 involvement reflects collaboration with a USPACOM partnering

country (Singapore) through special curricula. The meteorology involvement occurs due to both our own demonstrated atmosphere/effects models and procedures and the partners' need. The project applied models that related predictions and measurements to inputs for the effects models such as APM/AREPS (Rf) and TAWS/IRBLEM/EOSTAR (IR).

The MDSRP supported Applied At-Sea Technology Research Team's work was featured in the MDSRP SITREP, Volume 4, May 2004, "*Applied At-Sea Technology Research, Estimation of Atmosphere and Ocean Surface Influence on Radar and IR sensor Performance for MDP*," describing littoral region distance versus time-of-day variability of predicted two-way loss, exclusively caused by measured variability of atmosphere and ocean surface condition, during an August field test off Dam Neck, Virginia. Unclassified effects for a test of radar signatures of low cross section combatant craft were included.

Members of the At-Sea Technology Team were Drs. Kenneth Davidson and David Tucker, and Professor Rex Buddenberg.

POC: Dr. Ken Davidson (kldavids@nps.edu)

a. Atmospheric Detection Effects Prediction Tool (ADEPT)

NPS and collaborating groups are involved in the transition, for MDP, of technology and procedures for the estimation of lower atmosphere and ocean surface condition impacts on the detection of low radar cross section and low IR contrast targets, and the real-time display of the detection predictions in command centers and on operational platforms to aid in tactical decision making. A demonstration for such transition efforts, with special information on lower atmosphere and ocean surface conditions, was performed during the Trident Warrior/Silent Hammer (TW/SH'04) fleet exercise. TW/SH'04 was conducted off the U.S. West Coast in the vicinity of San Clemente Island, California, in early October 2004.

The collection and handling of meteorology and oceanography (METOC) data in TW/SH had two broad objectives; to address the requirement for METOC data to

be transmitted and made available by networking technologies for the operational decision makers; and to develop and demonstrate a concept for a tactical and operational planning decision aid which provides situational awareness based on real-time METOC data. The NPS objectives called for an integrated mobile adaptive networking platform with communication devices, supporting a satellite constellation approach for orbital data transfer. The NPS objectives also called for using collected METOC data as a tactical and operational decision aid and for improving situational awareness. This was accomplished by integrating in situ and satellite-borne sensor collected METOC data, external location mesoscale atmosphere prediction and analyses model data, environmental effects prediction model results, and the data transfer technologies of the first objective into a system for the in-field processing of the collected METOC data. The "system" that was developed and demonstrated was named the Atmospheric Detection Effects Prediction Tool (ADEPT).

The demonstration met the two major objectives and further analyses/ interpretation of the TW/SH data will be applicable to a variety of MDP situations in which predictions of RF propagation and optical sensor performance are critical to situational awareness. Principal participants on the ADEPT team included Dr. Ken Davidson, Dr. Alex Bordetsky, and LT Brian Harp, USN.

POC: Dr. Ken Davidson (kldavids@nps.edu)

b. Sensor Performance in Various Maritime Environments: Models to Planners to Sea

This project used atmospheric variables to answer the question: *Can propagation models and operational data support maritime interdiction operations (MIO) and surveillance requirements?* The project formulated and demonstrated tools to predict impact on allied and threat force near-surface platforms and people by radar or infrared waves, or intercept of communications. The technology incorporated and integrated multi-source high resolution airflow and surface data to predict airflow and surface impacts on radar detection and vulnerability and communications intercept during submarine operations.

Principle Objectives included: 1) test in field exercise adaptations/modifications of MSPP and Atmosphere Detection Effects Prediction (ADEPT) impact tools; and 2) develop models and procedures to meet needs of decision makers in submarine operations:

- NPS Bulk Surface Layer model
- Coupled Atmosphere Ocean Mesoscale Prediction System (COAMPS)
- Satellite Sensor
- Electro-magnetic (EM) propagation effects model and electro-optical (EO) target acquisition model
- Effects model

Milestones identified to fielding capacity included: 1) demonstrate operational use of tool; 2) field tests in surrogate locations; and 3) qualitative radar data and EO/IR data. Key deliverables included: 1) model formulation for detectability; 2) demonstration of impact estimation to detectability levels for first responders and communications; and 3) design and test platform sensors.

Key participants included Dr. Ken Davidson and Dr. Peter Guest of NPS, Space and Naval Warfare Systems Command (SPAWAR) Systems Center in San Diego, Fleet Numerical Meteorology and Oceanography Center (FNMOC), and USCG Research and Development (R&D) Center.

POCs: Dr. Ken Davidson (kldavids@nps.edu) and Dr. Peter Guest (pguest@nps.edu)

c. Atmosphere impacts on AIS transmissions for Maritime Defense and Security

A study in which predicted and observed atmospheric conditions were compared with received AIS signal data was undertaken. It was designed to improve predictions of AIS signal ranges. Also applied were knowledge and analysis tools on atmospheric and surface conditions that impact AIS signal reception. The latter are

refractive conditions that influence the range of surface emitted Rf signals, e.g. surface based ducts. The study focused on atmosphere and surface data obtained from coastal locations since these are more detailed than analyzed fields with regard to features that influence transmission. AIS ranges exhibited a high degree of variability related to seasonal coastal atmosphere conditions, with ships' signals detected at distances of up to 2,000 km.

Quantification of the impact on range with measurable and predicted atmospheric conditions will be the objective of ongoing studies, which will be guided by data compilation and preliminary results of this study. Figure 6 shows an example of the AIS signal analysis, to which operational meteorological data are applied.

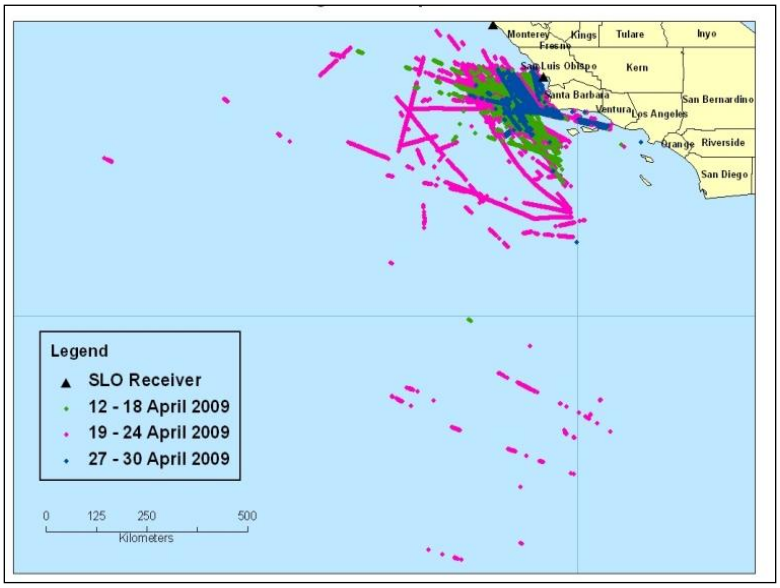

Figure 6. AIS signals, April 2009

The AIS signals from distant ships could be detected at coastal stations because transmission ranges were extended by atmosphere refraction anomalies. Shown are extended ranges for April 2009, divided into three periods that experienced short, medium and long ranges. From 12 -18 April, the ranges observed were moderate (green); from 19 – 24 April, the ranges were very large (magenta), and from the 27th -30th of the month, the ranges were quite short (blue). Observed and predicted atmosphere data, from operational forecast centers, and network provided observations are being related to these results.

In addition to such case studies, the study enabled collaboration with investigators of atmosphere refraction phenomena occurring around the globe. These collaborations have yielded atmosphere descriptions. These descriptions are key to suggested follow-on studies.

POCs: Dr. Ken Davidson (kldavids@nps.edu) and Arlene Guest (aguest@nps.edu)

d. SoS Approach for Atmosphere Impact for Singapore Region

MDSRP funding enabled cooperative research to begin with Singapore in FY11 to develop a system-of-systems (SoS) based on NPS atmosphere impact assessment methods, with USV platform measurement by Singapore resources (*see Figure 7).* Other planned program elements included: 1) to plan major marine defense field program with SoS approach; 2) to use knowledge and improved decision aids to create a network-centered operational procedure for best incorporating environmental information; and 3) to document system-of-systems fusion of all data to enhance surveillance systems performance in coastal regions.

Figure 7. System-of-Systems approach for atmospheric impacts in the Singapore region

Program objectives were to:

- Provide military, law enforcement and other security personnel with real time and future information on how the environment will affect anti-terrorist or anti-piracy operations in coastal and off-shore locations in the Singapore region.

- Develop, verify and improve models and procedures on the basis of comparisons of predictions with actual in situ observations of conditions and surveillance impacts.
- Develop and improve tactical decision aids (TDAs) for use in actual interdiction operations
- Use adaptive networks and other developing technologies for providing real time interconnectivity for situational awareness, data transfer and communication

Milestones to fielding capability were identified as:

- Perform rapid transition existing procedures and models to Singapore region, guided by system of systems approach
- Perform environmental impact predictions for the days of any Singapore-based field program, occurring within FY11
- Report or journal article with results and recommended tuning of TDAs for the Singapore region

Key deliverables will be a report on results and recommended tuning TDAs for the Singapore region, and an evaluation of the use of small unmanned boats for environmental measurements. Since this is an active research effort in FY11, the key deliverables will be post MDSRP.

POCs: Dr. Ken Davidson (kldavids@nps.edu), Dr. Tom Huynh (thuynh@nps.edu)

5. TNT/MIO: Environmental Effects Research

Observed and predicted atmosphere data determined the current and future conditions which, along with radar and optical sensor specifications, allow estimating the impacts of atmospheric profiles of temperature, humidity, aerosol and optical turbulence. Products were produced and made available to relevant personnel in easy-to-understand graphical formats using the TNT network (*see Figure 8*). Other important atmospheric

effects such as plume dispersion, sea state, precipitation and other weather events were predicted and displayed using different models but similar procedures.

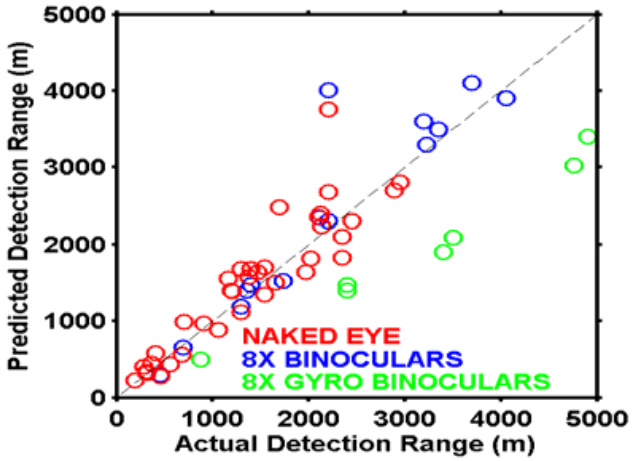

Figure 8. Example of atmospheric impacts on marine interdiction operations

In the future, such products will be automatically available on the world-wide web or a closed network for use by law enforcement and military group in the advent of an actual or attempted maritime terrorist attack. Shown below (*see Figure 9*) is the first responder vessel instrumented for tests. The position of instrumentation is indicated with an arrow. Low cross section cross-section identification occurred concurrent with optical detection.

Figure 9. Equipment used to measure atmospheric effects in field tests

Although heavily reliant on experimentation elements, this program was fundamentally research in nature. Members of this research team included Dr. Peter

Guest, Dr. Ken Davidson, Mary Jordan and Dick Lind of the NPS Department of Meteorology.

POC: Dr. Peter Guest (pguest@nps.edu)

6. Identification and Documentation of the Content and Structure of Existing National MDP Data Sources

One of the central challenges of MDA is the identification, tracking, and analysis of large numbers of moving assets. Not only must the volume of assets be identified and tracked in near-real time, but the number and variety of data sources is large, compounding the problem. These sources must be fused and analyzed in order to produce a timely result that can be acted upon, thus the need to design and build a prototype MDA system that can be evaluated for its effectiveness in thwarting maritime threats.

The core of an MDA prototype system is an MDA Data Warehouse containing cleansed and fused data collected from a variety of data sources. Data analysis, mining, and anomaly detection tools will enable analysts to access the data in the warehouse to support data analysis and the discovery of useful and previously unknown patterns and relationships. To this end, this MDSRP supported research effort focused on developing a prototype knowledge-based system to help intelligence analysts identify data sources needed to further analyze perceived threats. The prototype system would allow analysts to retrieve information about numerous data sources through a variety of flexible methods. These data sources include those maintained by the USCG, USN, DHS, Customs and Border Protection (CBP), the greater IC, individual State and commercial sources, foreign government sources, and open sources; and were collected from platforms, sensors, wireless, and terrestrial networks.

The overall objective of this MDA data effort was to address the issue of designing and implementing an MDA Data Warehouse, with a five-step development methodology: 1) define the data sources, 2) develop the data model, 3) cleanse and fuse the raw data, 4) populate the warehouse, and 5) provide data analysis, anomaly detection, and mining tools to access and analyze the data in the warehouse. These steps were

performed iteratively as design changes emerged during the various stages of development.

POC: Dr. Magdi Kamel (mnkamel@nps.edu)

7. MDA System Demonstration

There is no one intelligence source that provides enough data to allow for the definition of the Essential Elements of Information for MDA. This research project defined candidate architecture for MDA and identified tools and technologies to comprise a successful system for multiple consumers at multiple levels of security. Rather than build a new database, this project aimed to provide tools and portals to existing databases to be integrated into the stakeholder's existing workstations. MDA, a necessary part of any MDP system, requires access to applicable data sources, at all classification levels, and tools to manipulate and display data. This MDA System Demonstration effort focused on improving MDA by providing tools and portals that can be integrated into a stakeholder's existing workstation, providing faster access to more accurate and useful MDA information.

NPS faculty and students interacted with industry to evaluate tools under development for data fusion and tracking. The faculty also supervised two capstone design projects: 1) in the Space Systems Operations curriculum, which involved the design of architecture for a global MDA system; and 2) in the Joint C4I Systems curriculum, which involved the design of a command and control architecture for MDA.

8. MDA Sensor Fusion

In response to national strategy statements, several projects supported in part by the MDSRP set about to examine fusion of various information and intelligence sources concerning MDA. These projects sought to address specifically the directive within the National Plan to Achieve MDA (October 2005, http://www.dhs.gov/xlibrary/assets/HSPD_MDAPlan.pdf) to "Integrate and network existing platforms to enhance shared situational awareness. Likewise, ensure that all

future acquisitions are integrated and networked with appropriate sensor technologies (p. 15).”

a. National Sensor and MDA Fusion

An established classified and on-going program partially funded by the National Reconnaissance Office (NRO), MDSRP funding enabled greater participation with DoD Ph.D. candidates at NPS to address technical and security challenges.

Program objectives included:

- Develop an overall system architecture for the MDA enterprise
- Develop unusual data sources and evaluate their contributions
- Explore novel fusion techniques
- Evaluate existing fusion tools
- Develop enterprise level multi-tiered security solutions

Key project deliverables included: 1) a formal model and methodology for certification and accreditation of multilevel security (MLS); 2) an evaluation of a specific data source in the context of project *Fairgame*; 3) provide real-world data and information flows (*see Figure 10*).

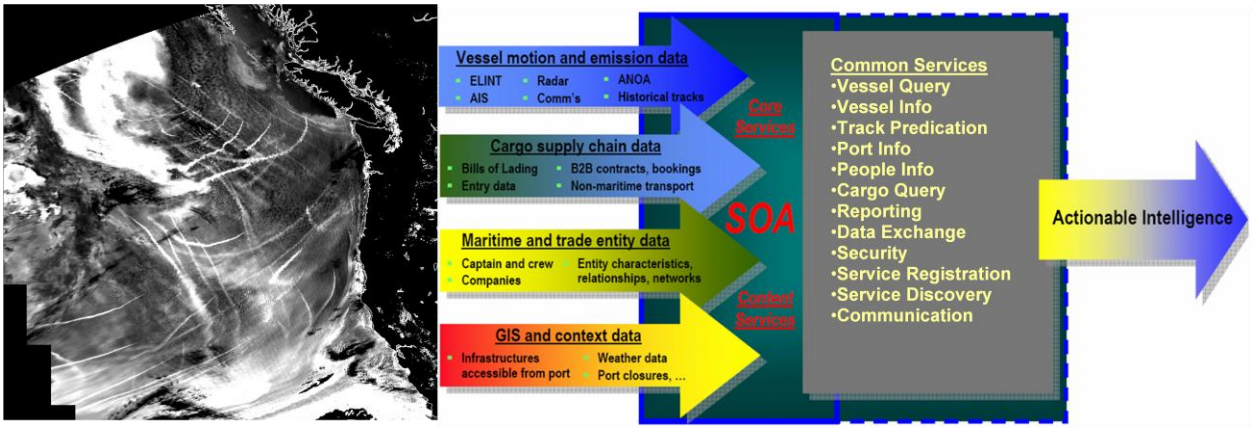

Figure 10. National sensor and MDA fusion model

Additional project funding beyond MDSRP came from U.S. Strategic Command (STRATCOM), NRO, Navy Tactical Exploitation of National Capabilities Program (TENCAP) and the DoD. NPS Professor Herschel Loomis led this effort.

b. Overhead and National Sensor Integration to MDA

The stated goal of this effort was to correctly detect ship track source positions, the for the initial manual detection methods leading to automated methods. This project also aimed to reduce uncertainties where possible using successive imagery, incorporate mean layer wind data to reconstruct source vectors, and add the ability to flag erratic or unusual behavior of source vectors (*see Figure 11*).

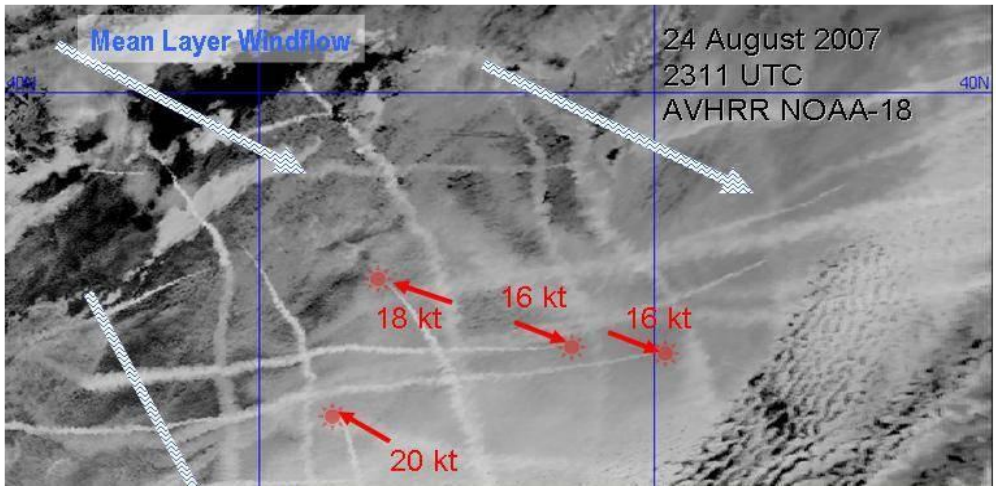

Figure 11. NPS ship track detect and analysis

An evolving project, the team intends to continue work on data fusion efforts for domain awareness, and develop end-product tools for this environmental data set.

POC: Dr. Herschel. Loomis

9. Optimization of Sensor Allocation for Search and Surveillance in Maritime, Littoral, and Urban Environments

Information-rich, dynamic environments require efficient and effective allocation of search resources to be successful. Success criteria include: 1) integrate multiple sources of diverse information for an aggregate awareness; 2) select and assign

appropriate search assets to refine representation of current world state; and 3) report and advise commanders on high likelihood locations for target presence. Currently, performance of search and surveillance in operational and tactical scenarios is limited by information-processing and decision-making capabilities. The results of this project endowed commanders with 1) a real-time search asset planning tool, 2) efficient integration of multi-source information, and 3) dynamic situational awareness representation.

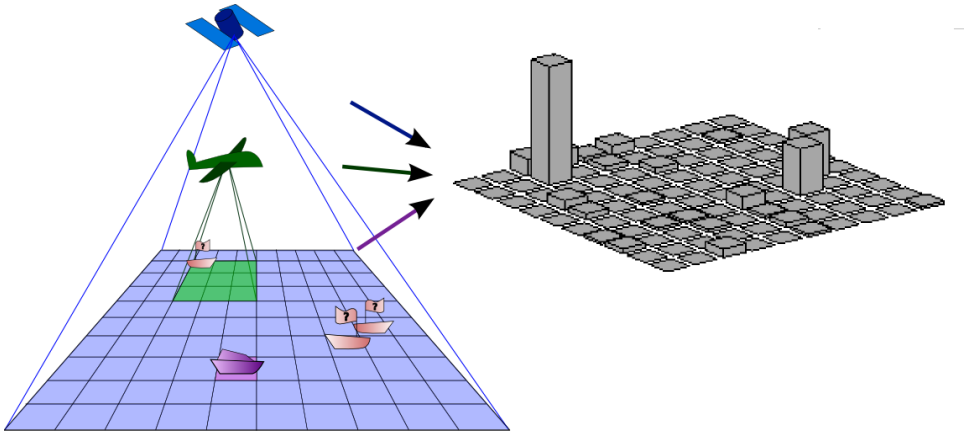

Figure 12. Optimization of sensor allocation for search and surveillance in maritime, littoral, and urban environments

The team used probabilistic modeling, implementing Bayesian filtering to support evolution of multiple target dynamics and achieve real-time integration of observation information. They also employed three-stage real-time rolling-horizon optimization of sensor selection, platform allocation and operation decisions (*see Figure 12*). This model was successfully demonstrated during Joint Expeditionary Force Experiment 2011 and adopted in a Navy tactics publication.

Primary team members include NPS faulty members Dr. Moshe Kress, Dr. Johannes O. Royset, and Dr. Timothy H. Chung.

POC: Dr. Johannes O. Royset (joroyset@nps.edu)

10. Assessment of Maritime Domain Protection Capabilities Maritime Intercept Analysis

Models for surveillance of waters around a port quantify the number of response platforms needed to address misclassification of neutral vessels as hostile. The system of systems consist of two types of platforms: sensing platforms and response platforms. Sensing platforms can detect possibly hostile vessels with error. Response platforms travel to the detected vessel to further investigate and possibly detain. The service time of a response platform tends to be longer than that of the sensor platform. The goal of this project was to provide quick-response analytical decision aids and planning tools, delivering an economical system of equations with solutions and graphs (*see Figure 13*) to suggest or indicate likely behavior of a new system-of-systems to ultimately guide often costly exercise planning and system acquisition. This work was completed at the request of ASD(HD) staff.

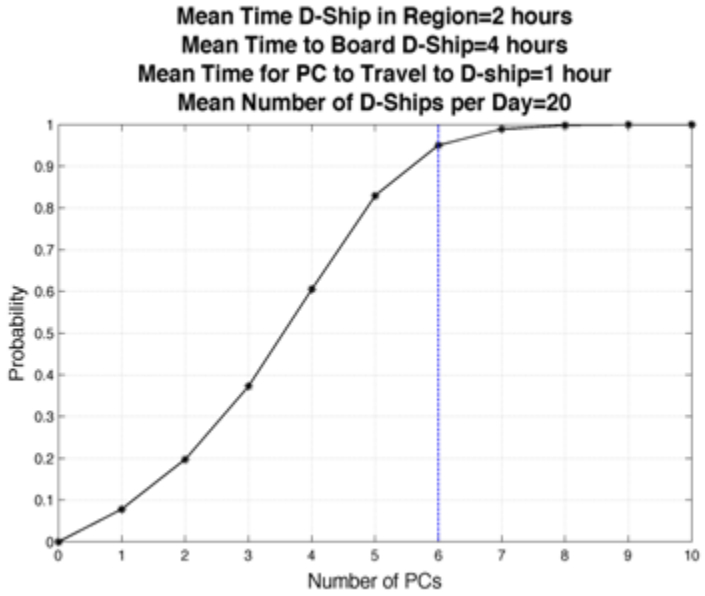

Figure 13. Probability hijacked D-Ship is inspected before reaching port

The overall technical objective was to improve and enhance the cost effectiveness of exercise and systems acquisition using analytical modeling and simulation by creating mathematical (probabilistic, statistical) models of entire system-of-systems. To meet this objective, the team conducted an operations analysis of a maritime domain awareness and protection problem. Researchers analyzed a scenario involving a hostile Red force, for instance small boats or other submersibles, arriving in a friendly Blue littoral domain, possibly near a port. The intent of the Red force was to cause damage after reaching land. The domain in the scenario was under surveillance, e.g., by one or more radar and IR-equipped aircraft, helicopters, or UAVs, possibly cued by a satellite-borne sensor. The littoral area contained neutral or White vessels, interspersed with hostile Reds: the Whites in the scenario could be mistaken for Reds, diverting the overhead sensor.

The goal of this project was to predict Blue force requirements, including numbers and types of Blue surveillance platforms and escort vessels, to determine effective CONOPS and minimize the "leakage" of lethal Reds through the littoral domain. Factors considered included the specification of the "random" rate of arrival of Reds, the density of Whites classified incorrectly as Reds, and the range and classification capability of the Blue sensors. The problem-solving approach used was to construct and manipulate quantitative models that predict the successful performance of various Blue forces against possible patterns of Red behavior.

The desired result was to limit the chances of lethal Reds crossing the littoral to valuable Blue assets on land or on targets such as oil-drilling platforms in the littoral. This result had to be achieved in a cost effective manner. The model’s parameters were allowed to be influenced by environmental conditions, such as "ducting," as well as dynamic evasive behavior by the Reds and the density of non-lethal White false targets. Model-formulation and manipulation is being actively pursued on various versions of generic homeland protection problems explored as war game scenarios. The results of this project provided considerable insight and assisted in intelligent design of exercises and actual operational planning.

Members of this Operations Analysis Team were Professors Donald P. Gaver (dgaver@nps.edu) and Patricia A. Jacobs (pajacobs@nps.edu), LT Brett C. LeFever (USN), Major Kim Chuan Chng of the Republic of Singapore Navy, and H. Sato from the Japanese military.

POCs: Dr. Donald Gaver (dgaver@nps.edu) and Dr. Patricia Jacobs (pajacobs@nps.edu)

11. Maritime Port Security and the Improvised Explosive Device (IED) Threat

A critical threat to commercial and military port security is a terrorist of state laid mine. Several MDSRP coordinated projects studied this threat and ways to counter it.

a. Analysis of Commercial Asset Effectiveness in Locating Underwater Explosive Devices in Domestic Ports

This project examined the detect and classify capabilities for Remus vehicles, and compared the navigational accuracy between Remus variants. As a baseline for future computer change detect software, the effect of bottom cluster density on change detection by operators was also determined. The primary research question centered on the accuracy gained from navigational system hardware and software upgrades on the Remus underwater vehicle. All types of positioning errors were taken into consideration. The focus of analysis on navigational error was to ensure accurate positional reporting of mine like objects for future reacquisition and prosecution. Analysis of bottom clutter effects on change detect performance was used to determine maximum levels of clutter in which change detection can be performed by current techniques. This baseline analysis was intended to be used to determine the effectiveness of automated change detect software.

The stated project goal was to analyze bottom clutter effects on change detect performance by current maximum levels of clutter in which change detection can be performed by current techniques. This baseline analysis was used to determine the effectiveness of automated change detect software. This project determined the probability of detect and classify methods for Remus vehicles and compared the

navigational accuracy between Remus variants. The effect of bottom clutter density on change detection by operators was identified as a baseline for future computer change detect software. To ensure accurate positional reporting of mine-like objects for future acquisition and prosecution, the analysis evaluated the accuracy of recent navigational system hardware and software upgrades on the Remus underwater vehicle compared with previous versions.

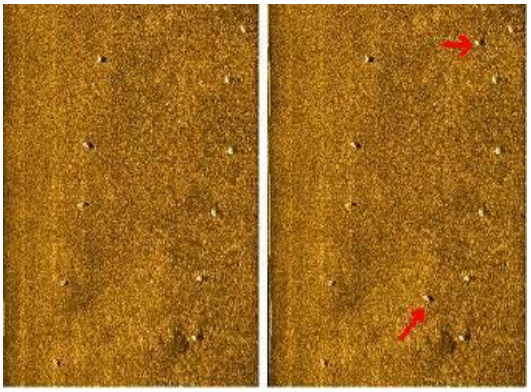

Figure 14. *At right,* side scan sonar image of initial bottom objects (Kline 5000); *at left,* side scan sonar image of same area at a later date indicating changes in bottom objects

The project objective was to analyze measures of performance as per Tactical Development Plan (TACDEV 08-03) and develop baseline change detect software parameters from current operational procedures (*see Figure 14*). Identified analysis milestones included:

- Assist in the development of the Data Collection and Analysis Plan for the San Diego Harbor Maritime Homeland Security (MHS) Experiment 9-14, December 2007 (*see Figure 15*)

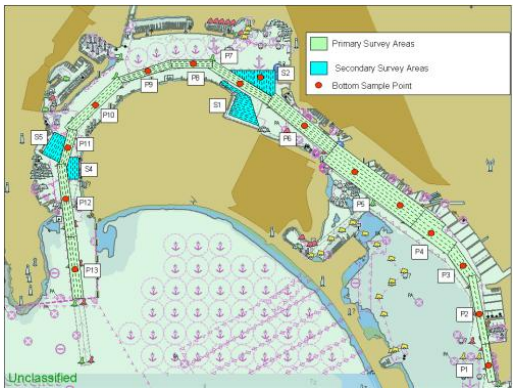

Figure 15. Chart of San Diego Harbor MHS Experiment areas

- Observe data collection operations in San Diego Harbor
    - Observe data collection with Orca Maritime (Remus UUV)
    - Observe data collection with EOD Unit 7 (Kline 5000)
    - Observe Post Mission Analysis performed by Orca Maritime
- Coordinate with Naval Surface Warfare Center (NSWC), Panama City and the Navy Warfare Development Command (NWDC) for receipt of remaining MHS data
- Perform change detect procedures with varying bottom clutter conditions
- Conduct analysis and publish results

Deliverables included a final report in the form of two NPS student theses that detailed 1) the effectiveness of commercial asset use in MHS scenarios, 2) the navigational accuracy of the Remus unmanned underwater vehicle (UUV), and 3) the minimum change detect performance for future software; all accompanied by supporting data including human change detect performance as a function of bottom clutter density. Key participants included NPS students LCDR Dale Johnson (MS Operational Research – OA, March 2008) and LT Jason Barrett (MS Operational Research – USW, September 2008).

POC: RADM Rick Williams, USN (ret.) (rdwillia@nps.edu)

b. Maritime IED (MIED) Cross Campus Study

In cooperation with the NPS JIEDDO research program, this study involved the fourteenth cohort of Systems Engineering Analysis students (SEA-14) and was published in December 2008 under the title "*Systems Approach to Defeating Maritime Improvised Explosive Devices in U.S. Ports*." Insight gained from terrorist attacks, training exercises, and intelligence intercepts over the past few years has shown a renewed interest in the use of mining as an effective means of disrupting commerce and damaging critical infrastructure. In an attempt to develop a system of systems architecture to defeat mines and maritime IEDs (MIED), the project team developed several system alternatives, or Adaptive Force Packages, that incorporate both existing systems and emerging technologies. Overall performance was assessed using a US Joint Forces Command sponsored war game simulating an MIED attack on ports based on the geography of Seattle and Tacoma. A critical analysis of the alternatives based on performance, suitability, cost, and risk were carried out. The study results showed that increases in performance are attainable with mixed results in cost and risk, and the report highlighted necessary actions and considerations that must be taken by military and civilian leaders in order to adequately prepare for and counter MIEDs in U.S. ports. The SEA-14 study concluded that primary to reducing the effects of an MIED attack to the maritime transportation system (MTS) is a standardized, nation structure that has the ability to 1) conduct baseline bottom surveys of ports and harbors, 2) process and retain the survey data, and 3) provide a timely and infrastructure-safe means of neutralization.

For more information, see the SEA-14 final project page at http://www.nps.edu/Academics/Programs/SEA/subpages/projects/2008Fall.html.

POC: RADM Rick Williams, USN (ret.) (rdwillia@nps.edu)

12. Anti-Terrorism/Force Protection Scenario Demonstrations for Risk Analysis and X3D Visualization

The NPS MOVES team updated exemplar facility-protection scenarios to illustrate risk elements and possible defensive responses. Software capabilities included production of 3D location and vehicle models (*see Figure 16*), as well as agent-based

tactics and rules of engagement for opposing and defending forces. The scenarios extended past proven work that permits quantitative analysis of risk, behavioral capture in agent-based behavior libraries, and visualization of scenarios to confirm realistic responses. Reports included a detailed plan for pursuing of potential follow-on work for a single facility and then Navy-wide deployment.

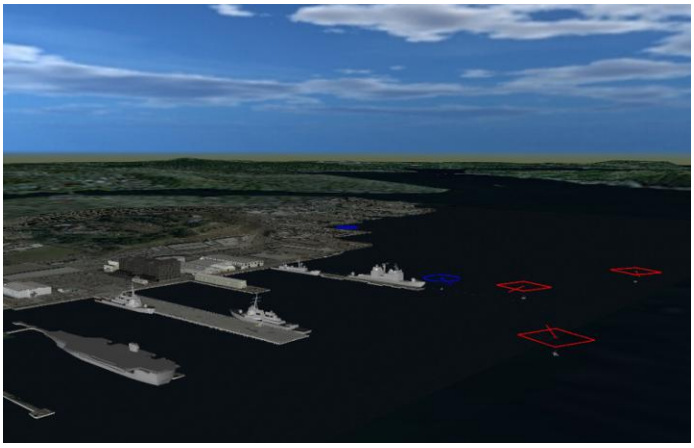

Figure 16. X3D visualizing of a potential terror threat to USN high value assets

In the first two phases, this project produced a lightly scripted tactical demonstration of how the developed tools illustrated risks and tradeoffs for naval facility protection. Using these tools, the team produced an analytic reporting statistical analysis of risk corresponding to various threat responses. Key deliverables included a summary report delivered to the Project Officer that included proof-of-capability demonstration results and the integrated facility-upgrade plan. Design considerations included display, tactical development, data collection, analysis, life-cycle methodology, and cost-benefit alternative recommendations for training. Recommendations for future work were also identified, including the creation of war gaming scenarios of interest.

Based on results and guidance from the second phase facility evaluation, the team produced a plan to enable deployment across all naval facilities.

POC: Dr. Don Brutzman (brutzman@nps.edu)

13. Center for Infrastructure Defense (CID)

By viewing our critical infrastructure through the eyes of intelligent adversaries, we discover how systems can be extremely fragile, and how we can mount effective

hardening and defensive efforts. Principle activities at the Center for Infrastructure Defense (CID) include understanding: 1) How infrastructure systems will respond to major disruptions – deliberate (e.g., sabotage, vandalism, terrorism, war) and non-deliberate (accident, failure, natural disaster); and 2) How to invest limited resources (for hardening, redundancy, or capacity expansion) to make these systems resilient to disruptions. To this end, the CID supported in part by the MDSRP has completed over one hundred "Red Team" case studies in the following areas:

- Energy: electric power, natural gas, petroleum reserves
- Transportation: roads and bridges, mass transit, ports
- Data and Voice Communications
- Emergency Preparedness and Response
- Supply Chains
- Site Security: airports, military bases, heads of state, Super Bowl
- Critical Project Management

Most recently, CID completed an analysis of the Hawaiian Island MTS. Results were provided to the USCG Captain of the Port (COTP). This work was supported by MDSRP funding.

POC: Dr. David Alderson (dlalders@nps.edu)

14. Maritime Domain Awareness: Tactics, Techniques, and Procedures (TTP) Process Definition and Reengineering

This work is direct support to USN efforts to develop a coalition and interagency MDA capability, including understanding interagency policy and technical barriers. Fully titled "*Maritime Domain Awareness (MDA) CONOP to TTP Process Definition and Reengineering Employing Network Centric and Services Oriented Architectures*", the intent of this project was to refine a project plan that documents process (*see Figure 17*), constraints to process and impact of technology as an input to CONOP and tactics, techniques and procedures (TTPs).

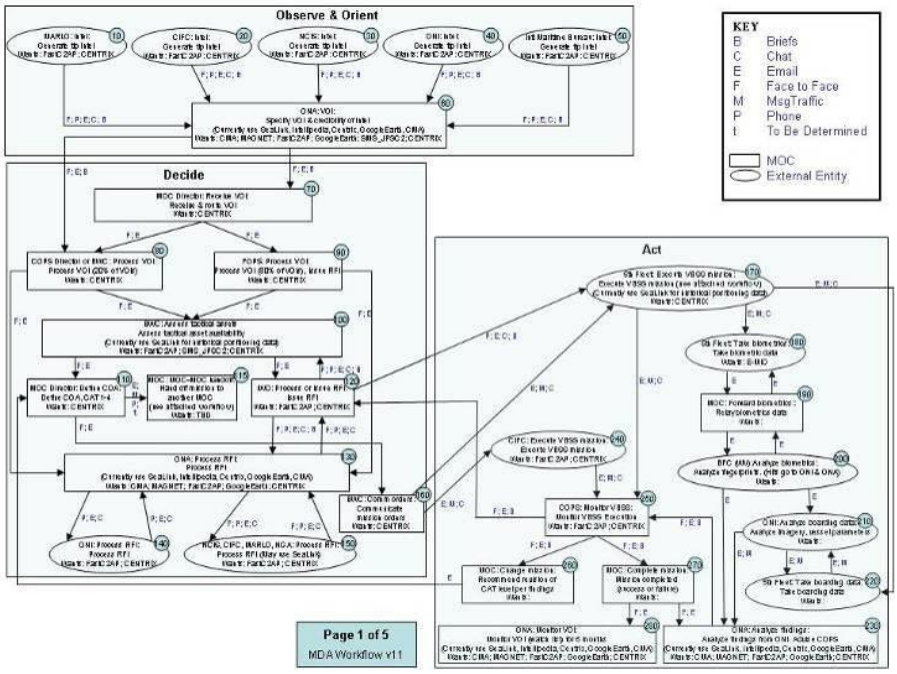

Figure 17. MDA workflow v11

The research focused around core operational threads (e.g., standard work flows, or "business practices"). Outcomes were further used for operational field experimentation in Trident Warrior 08 planned for execution in June 2008 and supporting venues for MDA Spiral-1 (*see report section II:C:7:a*). This project was intended to span two years; and provide feedback from this effort as well as TW08 outcomes and modifications back to Fleet participants, the Office of the Chief of Naval Operations (OPNAV), SECNAV and PEO C4I.

The two key objectives of this research were to 1) develop and manage a project plan that would provide CONOP and TTPs around core operational threads, and 2) to validate and adjust the project plan using input from operational field experimentation. In partnership with MDSRP, this project was also funded by OPNAV via PEO C4I. The milestones set for analysis were split into three phases (*see Table 2*):

Table 2. Analysis milestones for MDA TTP Process Definition and Reengineering

	TITLE	***TIMELINE***
PHASE 1:	Discovery	FY07
PHASE 2:	Process reengineering for improved TTP	OCT – DEC 2007
PHASE 3:	Delivery, validation and feedback/review of proposed TTP changes	DEC 2007 – DEC 2008

Key deliverables identified by the researcher included:

- "As is" process maps for current MDA work flows, information flows and TTP from Fleet Commanders
- "To be" process improvements for core MDA work flows
- Coordinated and congruent operational views (OVs), systems views (SVs) and technical views (TVs) between MDA Spiral 1, Trident Warrior 08, OPNAV N6, and NAVNETWARCOM
- Baseline MDA CONOP for input to NWDC for further CONOP development
- Baseline TTPs for specified core MDA processes
- Feedback report from Trident Warrior 08 and other venues derived by MDA Working Groups

POC: Dr. Shelley Gallup (spgallup@nps.edu)

15. A Maritime Domain Awareness (MDA) Framework for Seamlessly Sharing Data from Multiple Security Domains via a Service Oriented Architecture

The MDSRP partnered with the Navy Technical Capabilities (TENCAP) Program and defense-related R&D organizations to develop Radiant Alloy, a system (*see Figure 18*) that enables the development of a comprehensive MDA picture through the seamless integration and sharing of data across multiple security domains.

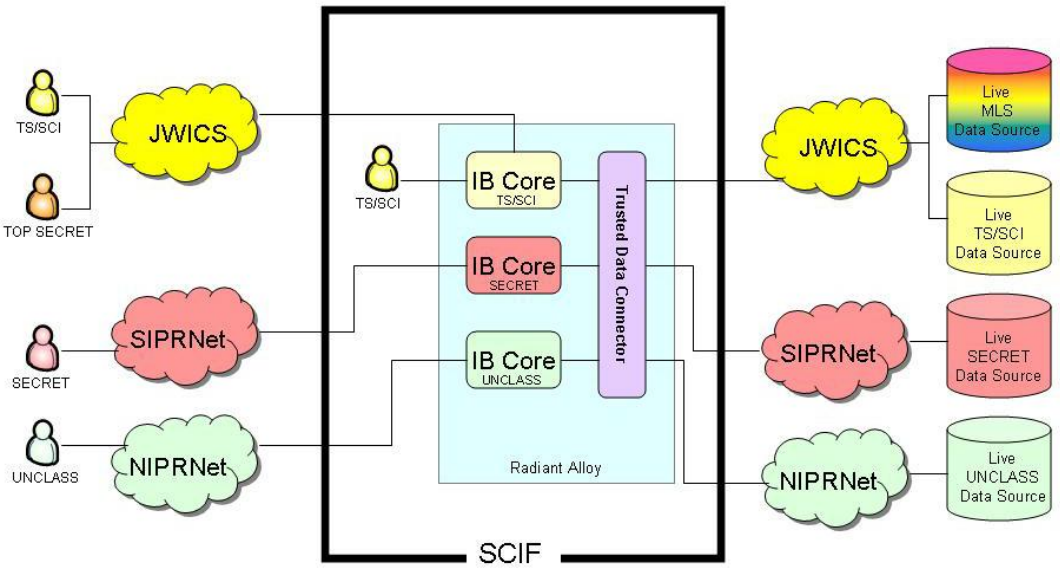

Figure 18. Proposed Radiant Alloy MDA system architecture

Under the direction of Professor Bret Michael, CDR Mike Schumann and MAJ Randy Arvay conducted research to provide the evidence necessary to certify and accredit Radiant Alloy for operation at the highest level of assurance. This research provided a foundation for a software engineering process to develop complex, enterprise-level, multiple level security systems based on service-oriented architecture (SOA) systems.

POC: Dr. Bret Michael (bmichael@nps.edu)

16. Maritime Information Sharing Taskforce (MIST)

The Maritime Information Sharing Taskforce (MIST) engages with government agencies and private sector shipping to improve the sharing of threat information. MIST is an interagency effort that receives support from the Department of Transportation (DOT), DoD, DHS, and the Office of the Director of National Intelligence (ODNI). Begun in 2008, MIST was a response to a national call for improved collaboration between the public and private sectors to help ensure safe and secure ports. By engaging local stakeholders in problem solving workshops (*see Figure 19*) and observing port personnel in action, MIST helps identify gaps and best practices in collaboration and information sharing, helps surface industry incentives for sharing, and helps explore the usability and usefulness of new security initiatives. In response to initial findings

showing the interdependence of the maritime, land, and air domains, MIST expanded their focus and changed their name in 2011 to include a wider representation of the supply chain. This new Multimodal Information Sharing Team focuses on engaging stakeholders across the shipping industry, including stakeholders from seaports, airports, trucking, rail and pipelines. To date, MIST has held five events throughout the U.S. at the ports of Los Angeles/Long Beach, the Puget Sound, Honolulu, the Delaware Bay, and Boston.

Figure 19. Researcher Anita Salem (*standing center*) in the MIST Puget Sound Workshop

MIST's research goals are to identify barriers, explore best practices, and recommend next steps in improving local information sharing. First, MIST findings show that there are a number of legal, cultural, procedural, and policy barriers to sharing threat information. 2010 findings show that industry-government information sharing is improved by addressing issues with interagency and industry collaboration, increasing cultural awareness, improving two-way communication, and aligning financial and social incentives to industry motivations. Second, MIST also surfaced a number of best practices for collaboration. These practices include the U.S. Customs Trade Partnership Against Terrorism (C-TPAT) program, the use of Facility Security Officer (FSO) subcommittees in Area Maritime Security Committees (AMSC), the expansion of industry run education programs for government employees, and the inclusion of industry in emergency preparedness activities and interagency operation centers (IOCs) in port environments throughout the nation. Finally, MIST identified opportunities for improving

the effectiveness of specific information sharing efforts. For instance, in 2010, by testing government initiatives directly with industry stakeholders, MIST participants helped identify ways to improve the usability of two existing information systems: 1) MARAD's MARVIEW and 2) the USCG's HOMEPORT. MIST also identified and detailed industry information sharing requirements. These requirements include the need for information that is useful (i.e. helps them in decision making) and is easy to access and use (i.e. centralized, available without a security clearance, and easy to navigate.)

The MIST findings illustrate the importance of building a partnership between the public and private sectors—an "All-of-Nation" approach—in order to improve the security of the supply chain. The findings are communicated to interagency partners to help inform national policy, are provided to local government agencies to improve collaboration, and are made available to industry to assist them in their port security assessments. All MIST reports are approved for public release and available upon request.

Cited previously in this report, the MIST project is one that is now independently funded, and will continue past the close of the MDSRP. Members of the NPS research team include Ms. Anita Salem, Ms. Wendy Walsh, Ms. Lyla Englehorn, Ms. Sarah Martin, and Dr. Susan Hocevar. Key partners include the DOT Maritime Administration (DOT-MARAD), the National MDA Coordination Office (NMCO), the ODNI Global Maritime and Air Integration Initiative (GMAII), and the USCG.

POC: Anita Salem (amsalem@nps.edu)

17. Towards Real-time System-awareness via Lexical Link Analysis: A Learning Agent Technology for Visualization of Unstructured Data

Systems of Systems (SoS) have increased in component, organizational, technical, and management complexity. This project is based on the assumption that the cognitive interface between decision makers and a complex system may be expressed in a range of terms or "features," i.e. specific vocabulary to describe attributes and surrounding environment of a system. The DoD Maritime Domain Awareness (MDA) Research is an extremely complex SoS, requiring constant collaboration and decision making. By

applying an innovative SoS approach using Lexical Link Analysis (LLA), agent learning, and visualization to generate dynamic "views" of elements, attributes, termed "features," to support large-scale decision making for MDA technology acquisition efforts as well as irregular warfare at sea, and intelligence collection/analysis automation. This research team is prototyping a multi-agent network of between ten and one hundred agents, that periodically learn, separate, extract and visualize interesting information from MDA technology acquisition data found from such sources such as DoD Maritime Strategy, Joint Integrating Concept (JIC), DHS Small Vessel Security Strategy, National Strategy for Automatic Identification System (AIS), Maritime Operational Threat Response (MOTR) Protocols, MDA requirements of functional needs analysis, capabilities-based assessment, Joint Capability Areas (JCA), Universal Joint Task List (UJTL) from Joint Requirements Oversight Council (JROC), User Requirements (e.g. US Northern Command and US Pacific Command), Gap Assessments, and Inter-agency Investment Strategy, among others.

The research team also worked with MDA open sources of intelligence ranging from vessel ID, location, images, piracy reporting, port operations, container tracking and security, weather, shipping schedules and lines, distance measurement tool, marine services directories, shipwreck database and casualty reports, maritime commercial activities and military exercises; and with the NPS High Performance Computing Center (HPC) to install these agents in the Hamming Linux cluster which provides the requisite supercomputing and visualizations for this project. Subtitled "A Learning Agent Technology for Data Separation and Visualization from Unstructured Data," the program objective is to train synthetic, computer agents to automate the tasks of recognizing patterns, separating, and visualizing important descriptions from unstructured data (e.g. text documents), and to facilitate and reduce the workload of decision makers and intelligence analysts who would otherwise perform the task manually.

This team also worked with the Modeling of Virtual Environments and Simulation (MOVES) Institute at NPS for 3-D visualization and real-time navigation through the LLA results using visualization tools such as X3D, AutoMap and Pajek. Additionally, one NPS Master's thesis has been completed on this topic.

Proposed milestones are broken into three phases as follows (*see Table 3*):

Table 3. Lexical link analysis proposed project milestones

PHASE 1	January – February 2010	Select application domain
PHASE 2	March – October 2010	Deliver a multi-agent network (between ten to 100 agents)
PHASE 3	November 2010 – December 2011	Deliver a real-time monitoring visualization interface to multi-agent network

Three identified principal tasks include: 1) analysis of collected data; 2) research and deliver a multi-agent network; and 3) build a real-time monitoring visualization interface (*see Figure 20*).

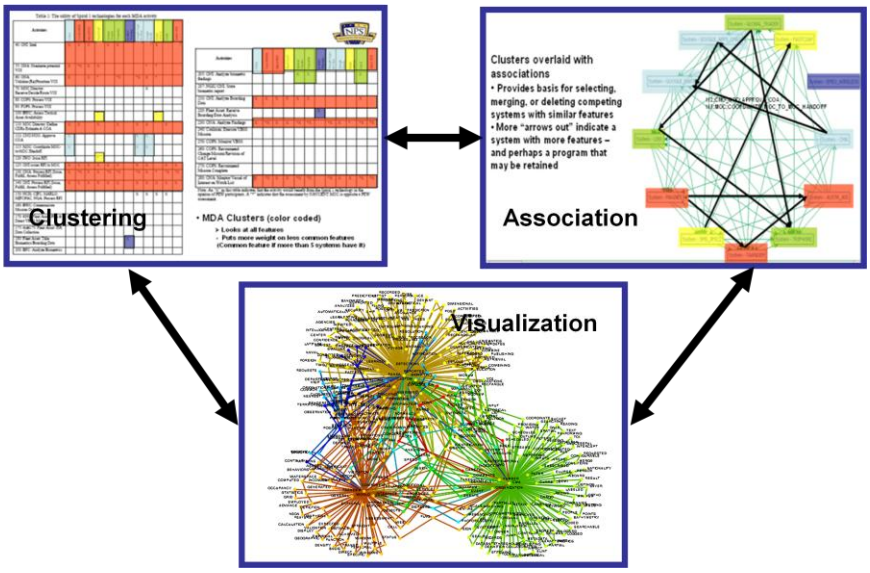

Figure 20. Example of lexical link analysis PHASE 1 visual representation

The first task involves analyzing collected data from large-scale experimentations at DISE/NPS, to facilitate acquisition decision makers in merging, deleting, and acquiring new systems and technologies as the results from the experimentation (*see Figure 21*). For example, Trident Warrior 10 (TW10) comprises data and myriad documents associated with selected technologies, residing in searchable databases such as ForceNet Innovation Research Enterprise (FIRE). This can help satisfy the need to connect what is conceptually important in the data of participating technologies and what warfighters need via CNO defined "Urgent Needs Statements" (UNS).

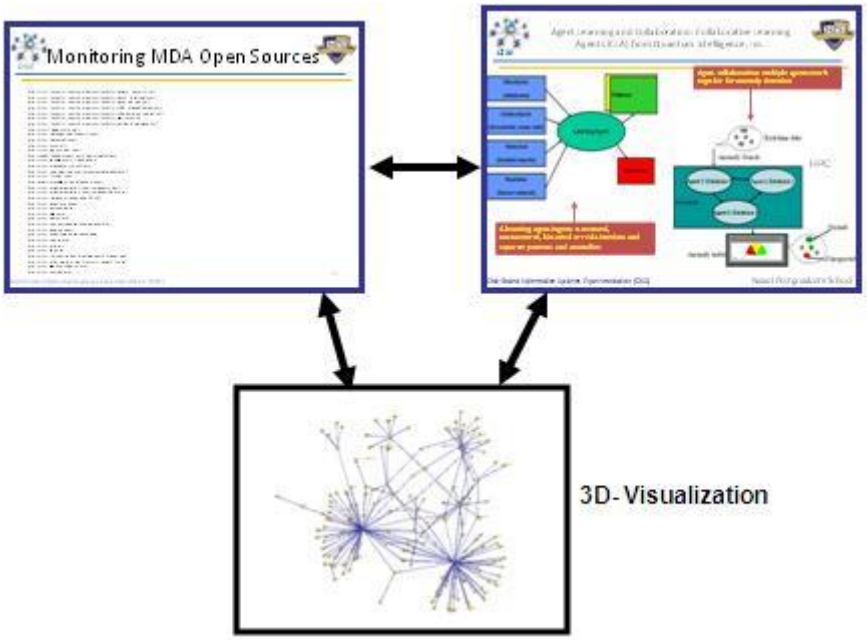

Figure 21. Lexical link analysis PHASE 2 paradigm

The second identified task requires the team to research and deliver a multi-agent network, e.g. ~10 to 100 agents, that periodically learn, separate and extract features from ongoing unstructured data collected in Task 1, perform data separation using the proposed agent learning and visualization techniques. Building a real-time monitoring visualization interface to monitor ongoing new technology trends that reflect in the newly discovered keywords of unstructured data will complete the third key task. This visualization will use a search to link the results, i.e. discovered keywords, back to the original documents for validation. Also the big picture needs to be updated and enhanced in real-time to eventually achieve multi-modal collaboration models range from exploring handheld devices to heterogeneous environments.

Members of this NPS research team include Dr. Shelley Gallup (Principal Investigator and Lead), Dr. Ying Zhao, and Dr. Douglas MacKinnon. Additionally, one NPS student member of this team was awarded the Distinguished Thesis Award for their work on this project.

POC: Dr. Douglas MacKinnon (djmackin@nps.edu)

18. Maritime Domain Awareness (MDA) and the Maritime Information Exchange Model (MIEM)

The U.S. and its allies consider excellent situational awareness about the maritime domain vital to national security. Current MDA efforts focus primarily on tracking vessels, people, and cargo as they move through waterways and transit facilities such as ports and particular businesses. While many different systems, belonging to many different agencies, participate in collecting and assessing observations about these entities, there has not been an agreed way to model and describe this information so collaborators could exchange, understand and incrementally improve it. The DoD continues to improve information sharing by making information assets understandable and accessible where: 1) understandable information consists of familiar *types* and *values*; and 2) information is accessible when computerized services can obtain it easily. "The key to achieving that goal was to create a set of types and values that could be used to describe beliefs about maritime entities, relations, and events, as well as the evidence for those beliefs. The *Maritime Information Exchange Model* (MIEM) addresses that need by prescribing how to express such beliefs and evidence (Dwyer, et al., 2009)." The MIEM, a joint project between the Naval Research Laboratory (NRL) and NPS, sought to accelerate production of actionable intelligence.

```
<?xml version="1.0" encoding="UTF-8"?>
<vesselSummary                    xsi:schemaLocation="http://miem.gov/md/1.0
../MIEM/1.0/miem.xsd"
sec:classification="U">
        <vessel id="VES0001">
        <identification>
            <name value="ATLANTIK EXPRESS"/>
            <callSign value="3E"/>
        </identification>
    </vessel>
    <vessel id="VES0002"/>
    <port id="PORT001"/>
    <port id="PORT002"/>
</vesselSummary>
```

Figure 22. The vessel ATLANTIK EXPRESS expressed in XML using the MIEM language

The MIEM is a conceptual model manifest in an Extensible Markup Language (XML) schema that prescribes how to describe and represent dynamic maritime situations, to express degree of belief and lines of evidence, and to build up comprehensive case files that both machines and humans can understand (*see Figure 22*).

Evolving out of work on a *Rich Semantic Track* (RST) conceptual model, the MIEM used XML, an open-source industry standard, to create a standard sharing language and common data structure for maritime related information. The MIEM provides clear and concise structures for expressing observations and analysts' beliefs about the vessels, people, cargo, facilities, relationships, and activities. As information is obtained, combined, analyzed and interpreted, the MIEM provides an abstract and flexible structure for representing the resulting beliefs and metadata about those beliefs. Use of the MIEM further increases production efficiency by allowing for the automation of simple processes currently performed by humans. With a common language defined, information can be seamlessly shared across the platforms, services, and agencies of the MDA COI. The MIEM is a language for building payloads in service-oriented communications such as those envisioned by the DoD Global Information Grid and Network-Centric Enterprise Services.

NPS delivered the first MIEM-based product to USCG's Maritime Information Fusion Center-Pacific (MIFC-PAC). That product automated the assembly of "targeting packages" for Vessels of Interest (VOI) from disparate information sources. These packages provide information about the vessel and its contents to USCG boarding parties. The MIEM provides the foundation for a collaborative approach to sharing and continually improving intelligence. To support the mandated move toward whole-of-government information sharing, the USN has established a partnership with the DHS Enterprise Data Management Office (DHS EDMO) and the program management office for the National Information Exchange Model (NIEM). Under this agreement, the MIEM has become the authoritative information sharing model for maritime data at the federal level (Dwyer, *et al.*, 2009). NPS work on this project concluded with assisting SPAWAR transition of the MIEM and the rest of the CMA JCTD.

POC: Dr. Rick Hayes-Roth (fahayesr@nps.edu)

19. MMOWGLI

Beginning in early Spring 2011, MDSRP supported personnel contributed as piracy SMEs to a new and innovative educational venture – the Massively Multiplayer

Online War Game Leveraging the Internet (MMOWGLI). MMOWGLI is an online game designed to find and collectively grow breakthrough ideas to some of our most "wicked problems." Many 21st century threats challenge stakeholders to try new forms of collaboration that can help create truly innovative ideas. In spring 2011, MMOWGLI launched by exploring a fast-paced interactive scenario of piracy off the coast of Somalia. Unexpected new forces are flooding the region, while cutting edge tools are pushing fleet capabilities and pirate tactics. Meanwhile political-economic disruptions mean that land-based strategies are just as critical as responses at sea. Invitations to join the MMOWGLI effort ask potential players:

- *What if you could remove any obstacle to turn the tide?*
- *What if you could collaborate with anyone?*
- *What if you had any resource you needed?*
- *What can we accomplish together?*

All ideas are needed. Join other innovators and creative thinkers from within and beyond the military. Preregister now at http://mmowgli.nps.edu Then, watch for a message this spring with your next instructions... and please forward this message to anyone else you think may want to play.

This project is in partnership with the Office of Naval Research (ONR), and is currently ongoing. Initial results from the counter-piracy games are being analyzed and will be released in report form when complete.

POC: Dr. Don Brutzman (brutzman@nps.edu)

B. EDUCATION

In addition to research projects, the MDSRP sponsored continuing education events, developed courses, and provided red team activities for the maritime defense and security community. NPS is viewed as a "neutral" player in interagency discussions, and the MDSRP was frequently leveraged as a facilitator for policy discussion. This section highlights some of those activities.

1. Maritime Domain Protection Symposium, August 2004

Held 18-19 August 2004, on the NPS campus in Monterey, the MDP Symposium brought together over fifty commands, departments, agencies, local law enforcement, and academic institutions involved in maritime security. During the two day event, numerous briefs were delivered on MDP, the status of MDSRP research projects and related efforts, providing a unique opportunity for members of the MDP community to learn about ongoing projects and share ideas. Symposium presentations were held at various levels of classification. Participants cited the many networking opportunities and the chance to establish new working relationships as one of the most valuable aspects of the Symposium. One of the more unique elements of this Symposium was the MDP Forum, in which in which visiting commands and participants were invited to present briefs relevant to MDP. The response to this invitation was very strong, with numerous briefs presented on a wide range of MDP topics.

This symposium provided the initial foundation for the National Strategy for Maritime Security, released as National Security Presidential Directive 41 / Homeland Security Presidential Directive 13 (NSPD-41/HSPD-13) in September 2005 (http://www.dhs.gov/xlibrary/assets/HSPD13_MaritimeSecurityStrategy.pdf). A collaborative interagency effort led by the Secretaries of Defense and Homeland Security to develop a national strategy for maritime security that built on existing efforts and resources, NSPD-41/HSPD-13 establishes policy guidelines to enhance national and homeland security by protecting U.S. maritime interests.

POC: Jeff Kline (jekline@nps.edu)

2. Maritime Security Education Courses

In response to specific CNO guidance in 2006 to "Develop a post-graduate education strategy centered around the Naval Postgraduate School's resident and distance learning programs that fully leverage Joint service, interagency, and international curricula," the MDSRP began working on a Maritime Homeland Defense and Security curriculum. Conceived and sponsored by Commander, Pacific Area and Commander, Third Fleet, the NPS Center for Homeland Security and Defense in partnership with MDSRP developed two pilot courses in Maritime Security Education: 1) the Senior Executive Leadership Seminar, and 2) the Interagency Maritime Security Planning course. Both courses were intended for an interagency audience and were taught by a mix of practitioners and academics from various maritime security organizations. These two courses were attended by over fifty students representing local, municipal, regional, state, and federal agencies.

Curriculum developers based their work on the assumption that the nation is progressing toward a mature maritime security war game and exercise program conducted at the local, state and national level. These are effective programs to test concepts, develop operating orders, and train current officials in positions of responsibility. The Maritime Security Education initiative is viewed as a natural outgrowth from these war games and exercise programs. Its purpose is to educate or renew information for officials assuming responsibilities associated with maritime security in national and state directives, current threats, integrated information processes, and interagency procedures.

Primary learning objectives included:

1) Assist Federal, DoD, and State executive leadership to build on existing successes in Homeland Security and Defense (HLS/D) preparedness, and strengthen capacity to prevent and defeat terrorism;

2) Summarize the role of DoD response within the context of Presidential Directives, Homeland Security National Strategy, and the National Response and Preparedness (NRP) framework; and

3) Analyze MDA and appropriate use of Maritime Homeland Security/Defense (MHLS/D) assets to national maritime threats.

As a result of the success of these initial courses, this curriculum is now offered at the Naval War College.

a. Senior Executive Leadership Seminar

The first of two pilot courses in Maritime Security Education developed with MDSRP support, the Senior Executive Leadership Seminar was a one day seminar designed for senior officials and flag-level officers. The initial offering of the seminar at the NPS Center for Executive Education in August 2006 was evaluated as effective by 21 participants with an average ranking of 4.6 for overall experience and 4.35 for course content on a five point scale. A modified version of this seminar is still part of the CEE curriculum.

This elected official, senior executive service and flag-level one-day course addressed current national, state, and local constructs for maritime security using a scenario based seminar style format. Participants were divided into smaller working groups to address specific issues related to the maritime threat to the U.S. homeland presented through real-world scenario analysis. The seminar was held at the unclassified level to allow interagency, state, and local participation. Learning objectives included:

1) Gain familiarity with current terrorist organizations posing a threat to maritime security and examine U.S. agencies associated with collecting intelligence in this area;
2) Discuss the various authorities used to conduct operations to detect, deter or defeat a maritime terrorist threat, the decision making process involved in designating authority, and the impact of those decisions;
3) Address the issues related to integration of federal efforts with state and local authorities and first responders to a maritime security threat; and
4) Review the latest Maritime Operational Threat Response (MOTR) guidance and C3F/PACAREA MHLS/D CONPLAN.

The two scenarios reviewed during this pilot course focused on the Long Beach/Los Angeles area. The first scenario involved a shipping threat to the port with a week-long intelligence lead time that included potential damage to port infrastructure. The second scenario was a surprise attack against a cruise ship moored in Los Angeles harbor. Each threat highlighted various issues related to interagency coordination in preventing and responding to a maritime terrorist attack.

b. Interagency Maritime Security Planning Course

The second of two pilot courses in Maritime Security Education developed by the MDSRP, the Interagency Maritime Security Planning Course was a four day mid-level official planner's course. The initial offering held in San Diego from 19-22 September 2006 was evaluated as effective by 29 participants – with an average ranking of 4.4 overall, and 4.08 for course content on a five point scale. The course mission was to educate military officers (0-4/0-5/0-6), DoD civilians, and Federal and State agency members to ensure the readiness of their MHLS/D missions; and to introduce National, State, local and DoD statutes, directives, plans, C2 relationships, and capabilities with regard to MHLS/D response. This course is now part of the Naval War College curriculum.

POC: Jeff Kline (jekline@nps.edu)

3. International Maritime Security Program

The common good derived from freedom of the seas is difficult to overstate. International waters are the backbone of global trade. Maritime security then becomes an interest to all nations who rely on the sea for trade or resources. This course sequence seeks to address issues related to maritime security, from threats to resources required to establish security internationally and in coast regions.

Building on the curriculum work done to support the Maritime Security courses in 2006, the MDSRP was tasked by the International Military Education and Training (IMET) program to develop a three course sequence exploring all aspects of Maritime Security on a global scale. To that end, development of a maritime security certificate

program was included as part of the academic year 2009 Naval Postgraduate International Military Education and Training course development initiative. The initial tasking requested a three course certificate program designed for 90 hours contact time. These first three courses were intended as a stand-alone certificate program and for its potential inclusion in a graduate degree program in public administration with a specialty track in maritime security. This certificate program and possible specialty track currently has three completely developed courses ready to be delivered to an international military student audience: 1) Introduction to Maritime Security and Planning, 2) Inter-Organizational Collaboration and Maritime Security, and 3) Maritime Security Resource Planning.

Work is ongoing to find the best venue and delivery framework for this very important course sequence, with plans to incorporate this curriculum into an International Masters in Public Administration (I-MPA) to be delivered in partnership with international academic institutions.

POC: Jeff Kline (jekline@nps.edu) and Lyla Englehorn (laengleh@nps.edu)

4. Standing Red Cell Support for Maritime Security Operations

The MDSRP leveraged NPS students to become Red Cell members with analogous knowledge levels typical of real terrorist cell members to address currently relevant threats and problem sets. Typically, a Red Cell team conducts research and enemy CONOPS planning from unclassified sources. The team then incorporates vulnerability assessments into studies, war games, and exercises to test potential countermeasures or security procedures. Key program objectives include developing potential terrorist courses of action to disrupt maritime security operations, incorporating results into vulnerability assessments, improving awareness of potential terrorist threat options, and contributing to the improvement of maritime security by informing improved countermeasures or procedures.

The MDSRP supported a plethora of Red Celling across a wide variety of topic areas and projects. The three included in this report (*see Table 4*) are only a representative sampling.

Table 4. Representative sampling of MDSRP Red Cell activities, 2004-2011

2006	U.S. Navy Ship in Foreign Port, sponsored by ASN (RDT&E)
2008	West Coast Port Attack, sponsored by the California Office of Homeland Security (OHS)
2009	Attack against merchant, sponsored by the U.S. Department of Energy (DOE)

POC: Jeff Kline (jekline@nps.edu)

a. Assistant Secretary of the Navy – Research, Development, Testing & Evaluation (ASN (RDT&E)), 2006

This effort was in response to the Office of the Secretary of Defense – Acquisition, Technology and Logistics (OSD-ATL) and the Assistant Secretary of the Navy – Research, Development, Testing and Evaluation (ASN (RDT&E)) vision to develop analogous Red Cell at NPS to highlight national vulnerabilities. The resulting Red Cell group consisted of operationally experienced officers, but not subject matter experts about potential targets. This group was then tasked to develop attack concept of operations and logistics from unclassified sources. NPS added a war game evaluation element to the effort. Their first tasking was a scenario involving an attack on a U.S. ship in a foreign port.

The stated mission was: develop a terrorist plot using strictly unclassified sources in order to create a disturbance and embarrassment against the United States Navy while at a foreign port. The teams used open source data to develop their concept and trace logistical support. Red Cell investigated various foreign ports based on the following:

- Historical/repeated visits
- Vulnerabilities in host nation authorities
- Accessibility for importation of logistics
- Location, anchorage points, and web-photos

- Liberty Boat time schedules and routes
- Port facilities and harbor master contact information

Acapulco was chosen as the scenario locale to conduct a phased attack consisting of an underwater IED, rocket-propelled grenade (RPG), ambulance vehicle-borne improvised explosive device (VBIED), and airborne attack against a USN ship at anchor on or about 4 November 2006. This location was ideal for this scenario because:

- Approximately 20-25 USN and USCG ships visit Acapulco annually
- There is a Mexican Naval base on the southeast side of Acapulco Bay that is never used for U.S. ships
- It is the second largest port in Mexico, Cozumel being the first
- There was a U.S. Navy Air Show scheduled there for 4 November 2006

The phased operation maximized USN vulnerabilities by:

- **Sea**: Time-delayed underwater IEDs targeting anchorages
- **Land**: Two-stage attack against USN personnel at liberty landing
- **Air**: Small aircraft targeting USN vessel or aircraft (suicide)

The Red Cell Composition included five distinct units (*see Table 5*).

Table 5. ASN RDT&E Red Cell proposed composition, 2006

HQ Team	1- Red Cell Ldr/HQ (Arab), Serves as the spotter and can control the remote/command detonator for Ambulance IED
A-Team "Ambulance"	1- Driver in uniform (Mexican) 1- EMT in uniform (Arab)
B-Team "Boat"	1- Boat Operator (Mexican), with help of EMT
C-Team "Cessna"	1- Pilot (Arab) operates alone and serves as a 2nd pair of eyes.
D-Team "Taxi"	1- Driver (Mexican) 1- RPG shooter (Arab)

The NPS Red Cell group detailed an insertion plan, logistics (including budget) for the proposed attack, and material requirements. These were all detailed in a logistics matrix developed from unclassified sources.

A Blue Team made up of surface warfare officers (SWOs) was tasked to develop an in-port security plan (ISP) in accordance with Commander, U.S. 3rd Fleet (C3F) guidance. Their basic mission was to implement an in port security plan to counter possible terrorist threats. The practical execution of this add-on war game effort took place in one full eight hour day, 1 September 2006. Three faculty and five staff, four Blue Cell students, four Red Cell students, and two Green Cell members (played Host Nation) engaged within this scenario. This war game used computer visualization for situational awareness.

The war game results coalesced into three primary takeaways: 1) the underwater attack was unsuccessful because Red Cell planted mines at the wrong anchorage; 2) the land attacks were successful because there were extensive casualties at the fleet landing, and slowed the ships emergency recall of its crew ashore; and 3) the air attack was successful although there was minimal damage to ship (superstructure only), few casualties from direct attack, and the casualties from secondary fires were unevaluated. Key Blue Cell lessons learned were 1) consider alternative fleet landings, 2) request non-published anchorages/moorings, 3) vary from published arrival schedule particularly during high visibility events, and 4) provide security and alternative return paths to the ship during emergency recalls. Faculty evaluators noted that Red Cell successfully developed a feasible concept of operations from unclassified sources; the host nation security (Mexico) and Navy AT/FP (NCIS) was not actually challenged, so terrorist insertion, integration, and attack execution may have been foiled; and the war game element to this Red Cell effort added significant insights in tactical execution by all three cells. These red cell's plans and following war game results were briefed by the student participants to the ASN (RDT&E) and ten flag officers in Washington D.C.

b. West coast port attack, 2008

Specially selected and screened students from NPS and the Monterey Institute of International Studies (MIIS) were tasked to characterize vulnerabilities

associated with the California Port System and to develop detailed CONOPS to exploit its vulnerabilities. Three teams of approximately ten students aided the security interests of the State of California by the supporting California Office of Homeland Security's (OHS) *Golden Guardian 2009* Homeland Security exercise. The NPS project portion of this exercise focused on using open source information to find specific vulnerabilities with California ports.

Major Vida Beard and Major Brian McCullough, both from the National Security Affairs Department in the NPS School of International Graduate Studies (SIGS) led two teams comprised of joint students from a cross-section NPS and MIIS. On 10 April 2008 the teams from this student-led Red Cell exercise, briefed California OHS officials on their initial planning efforts. Over forty personnel, consisting of faculty, OHS members, local law enforcement and MIIS and NPS students attended the briefings at NPS. The stakeholders from OHS planned to take the results of the study back to the Governor's Office to be considered for inclusion in the state's Homeland Security Exercise Program, *Golden Guardian 2009*. The briefings were the culmination of planning efforts of two teams over the first two quarters of 2008. The students were tasked with investigating problems and weakness with California's port system. The briefings contained innovative strategies and concepts pertaining to the security of the state of California consistent with the tenets of the NPS MDSRP. Over thirty students across two red cell teams, participated in the homeland security endeavor, and drew on a wide array of military, academic, and personal expertise.

This Red cell effort demonstrated the value of partnership between federal and state entities by delivering meaningful products to the State of California. The activity also advanced the education of future national security and homeland security leaders at NPS and MIIS.

c. Department of Energy (DOE), 2009

This work was accomplished to elevate risk mitigation strategies for transport of sensitive material. The results were provided to DOE and are classified.

5. Panetta Institute Interns

Between 2004 and 2011, the MDSRP sponsored three interns from the CSUMB Panetta Institute's Master of Public Policy (MPP) program. The first Panetta intern, LT Bruce Martin of the Marina Department of Public Safety, joined the MDSRP in August 2004. LT Martin assisted with the development of a federally funded program to teach command and control (C2) procedures for law enforcement, including foreign language and cross-cultural components. As a Hazardous Materials Responder and Incident Commander, certified firefighter, and graduate of the FBI's National Academy, LT Martin brought the expertise and viewpoint of local law enforcement to MDSRP goal of improving MDP. Participation in the August 2004 MDP Symposium helped him re-focus his research on current local, possibly regional, issues related to law enforcement, firefighting policies, and national security matters. After the symposium LT Martin wrote, "The need for an integrated system, or at least better integration, between DoD, Federal, State and local authorities, particularly related to MDA issues, is clear. Individually, we have inadequate resources and no coordinated, local emergency plan(s) to handle crises at major tourist draws or significant power installations. This could impact traffic movement and delivery of critical power (SITREP, vol. IX)." His final thesis in the form of an applied policy analysis report was titled "*Requirement for Local Maritime Domain Awareness Training*."

In October 2008, Panetta Institute graduate student Ms. Lyla Englehorn was brought on to assist the MDSRP funded MIST project with their research effort in the Puget Sound region. Her thesis, "*Maritime Domain Awareness and Regulatory Clutter*," a direct result of her work with MIST, was briefed at the July 2011 monthly MDSRP meeting and then forwarded on to national level MDP stakeholders for review. After earning her MPP degree in May 2010, Ms. Englehorn has stayed on with NPS as a Research Associate with the National Security Institute.

Ms. Rebecca Law, the third and final Panetta Institute intern with MDSRP, started her work supporting the curriculum development efforts for the International Maritime Security courses in late 2009. The policy recommendations in her thesis addressing the root causes of contemporary piracy, "*Maritime Piracy off the Coast of Somalia*," have

now been incorporated into the MOVES Institute's MMOWGLI project (*see report section II:A:19*), an experiment in generating collective intelligence.

POCs: Jeff Kline (jekline@nps.edu) and Martha Diehl (mpp@csumb.edu)

6. Port Security Visit, Oakland CA

In late 2004, members of the MDP-RG ventured to the port facility in Oakland, California, for a day-long visit. Students from the NPS SEA curriculum and California State University, Monterey Bay (CSUMB) participated. The focus of the site visit was port security and protection of the vital intermodal transportation system that ties the world together. Students met with representatives from the Port of Oakland CBP, and APL (www.apl.com). This event presented an opportunity for students to interact with security experts from both government and industry, providing a better understanding of the current state of maritime protection, cargo security, and possible implications for the DoD.

This visit was a first step towards creating a framework for future information exchange in support of maritime security, MDSRP, and the SEA-7 integrated student project (*see report section II:A:1:a*). The day-long meeting included presentations covering a variety of topics, such as detecting weapons of mass destruction, working with trade unions, cargo containerization, implementation of radiological sensors, real estate laws, and the scrap steel trade. Students also toured the APL container yard and a handful of students toured the M/V PRESIDENT GRANT, a 52,000 deadweight ton American Flag containership.

POC: Bruce Martin (bruce.martin2@yahoo.com)

7. Maritime Security Workshops

The MDSRP program supported faculty and students to participate in an ongoing series of workshops with maritime security partners in Singapore. A series of security meetings organized by the Temasek Defence Systems Institute (TDSI) in Singapore with U.S. partners at NPS, and LLNL, this effort began in 2002 and was carried on by the

MDSRP starting in 2004. An annual event, this report only highlights the last four years of activity. It is anticipated that this effort will continue on past the close of the MDSRP.

POCs: Dr. Tom Huynh (thuynh@nps.edu@nps.edu) and Dr. Don Brutzman (Brutzman@nps.edu)

a. Globalization and Maritime Security Conference, Virginia 2008

The Cebrowski Institute and NPS hosted the 2008 *Globalization and Maritime Security Conference* in Crystal City, Virginia, 29-31 July 2008, as an interdisciplinary research and education Security and Global Effects Initiative. The goal of the international conference was to provide a forum for researchers and sponsors to share information, research and insights related to globalization and maritime security. Divided into two discussion groups, participants attended either the globalization track to focus on conflict prevention, globalization systems and leadership in complex environments or the maritime security track to discuss global maritime partnership, maritime security technologies and port security for the Straits of Malacca and Singapore. The conference also featured plenary discussions and collaborative working groups for the development of new ideas, future research and follow-on activities.

Guest speakers for the sixth security workshop included the Vice Chief of Naval Operations Adm. Patrick Walsh, who delivered the conference keynote speech, Deputy Assistant Secretary of Defense Gregory Gross, Cynthia Irmer of the Department of State, Rear Adm. Lee Metcalf of the Office of Global Maritime Situational Awareness (OGMSA), Maj. Gen. Herbert Altshuler of U.S. Africa Command, Deputy Assistant Secretary of Defense Donald Loren, Senator Gary Hart, Brig. Gen. Tan Yih San of the Singapore Ministry of Defence, NPS President Dan Oliver and NPS Provost Leonard Ferrari.

Tom Huynh and Don Brutzman, chairmen of the Maritime Security track, reported that the Singaporean visitors expressed their pleasure in the success of the conference and felt the organization and format were very productive to the collaborative process. The Globalization and Maritime Security tracks facilitated and chaired by NPS faculty Dan Boger, Karen Guttierri, Don Brutzman, Tom Huynh, Mitch Brown, Peter

Walker of Tufts University and Jean Tulley provided a strong structure for the collaborative process. The Maritime Security track included discussions of the Straits of Malacca and Singapore projects assessing the effectiveness of advanced sensors and defensive technology, integrated with existing assets to create higher levels of security. The Globalization Track included topics of trends, shocks and prevention and leadership development in complex environments. The Singaporean delegates expressed that this was the most successful and well organized Globalization and Maritime collaboration between Singapore and NPS to date and will serve as a framework for future collaborations.

b. 7th Maritime Security Conference, Singapore 2009

The 7th Maritime Security Conference took place in Singapore, 15-17 July, 2009 as part of a series of security meetings organized by TDSI in Singapore, NPS, and LLNL. The objective of this workshop was to solidify collaborative research projects in seven key research areas, maritime security being one. The product of this workshop was a research plan detailing specific research projects related to those research areas, researchers to collaborate in those projects, and specific roadmaps to the realization of the projects.

c. 8th Maritime Security Conference, Monterey 2010

In April 2010, NPS hosted the 8th Maritime Security Conference near the Monterey campus. Visiting Singaporean attendees included representatives from the Ministry of Defence (MINDEF), the Defence Science and Technology Agency (DSTA), the Singapore-MIT Alliance for Research and Technology, the S. Rajaratnam School for International Studies, and the National University of Singapore (NUS) from both TDSI and the Mechanical Engineering School. Joining several NPS researchers from a variety of departments were representatives from LLNL, the University of Wisconsin at Madison, and ONR Global. Presentations on featured research included:

- Maritime security in a mine warfare environment
- Maritime security in an unmanned/remotely piloted environment

- Maritime security using autonomous vehicles
- Hyperspectral imagery analysis using spatially rectified data
- Streaming hyperspectral imagery analysis
- Hyperspectral image analysis to locate targets that are not spatially resolved (or resolvable
- Defense against "Ship as a Weapon" (SAW)
- SoS approach to exploiting knowledge of atmospheric and ocean surface impacts for maritime defense and security
- Multilayer functional composites for personnel protection against IEDs
- A multilevel secure device for transient tactical access to sensitive information
- Architecting of netted sensors for persistent surveillance under uncertainty

This full three day event included a site visit to NPS's experimentation site at Camp Roberts, a tour of NPS campus resources and meetings with key personnel, as well as group social and dinner events.

d. 9th Maritime Security Conference, Singapore 2011

Held on the NUS campus in July 2011, the 9th Maritime Security Conference was jointly organized by TDSI, NPS, and LLNL. The ninth in a series of annual meetings, this workshop focused on four primary research areas:

1) Unmanned technology
2) Sense-making
3) Cyber security, and
4) Maritime security

The objective of the workshop was to solidify collaborative research projects in these four research areas between all participants. The product of this workshop was a research plan, containing related research projects, identified researchers to collaborate on the specific projects, and plans for how to proceed. The approach used in the workshop to achieve the stated objective involved conducting parallel track meetings corresponding to the primary research areas. For each track, participants held brainstorming discussions using a template distributed in advance to capture ideas, then

turn the discussions to the specific research areas. Leadership of the participating institutions were provided an opportunity during the workshop proceedings to share feedback, facilitating collaborative proposal development.

This two day event included several keynote addresses by prominent SMEs in the research areas selected, project updates on featured research, and a full group dinner. Attendees included representatives from Nanyang Technical University (NTU), NUS, NPS, DSTA, MINDEF, DSO National Laboratories, the Government of Israel, LLNL, ONR Global, ONR USN, the Institute of High Performance Computing (IHPC), the CNA Institute for Public Research, the Singapore University of Technology and Design (SUTD), and the NMIC.

8. Project Looking Glass

The MDSRP sponsored NPS participation in the January 2005 ASD(HD) war game "Project Looking Glass," an interagency game billed as a Maritime Homeland Security/Homeland Defense war gaming exercise. The resulting analysis of the various linkages was intended to focus future MDA efforts. Combining link analysis with dynamic steps and feedback was identified as a likely next step. Anticipated results were provided to appropriate commands, agencies and enterprises for requirements and policy generation as well as offensive and defensive implications and considerations.

9. Requirements, Capabilities, and Technology (RCT) Forum, May 2005

The USCG's MDS Program Integration Office and the MDSRP hosted a Requirements, Capabilities and Technology (RCT) Forum on 2 May 2005 at the Santa Clara, California, Convention Center. The RCT Forum was a preliminary event to the four-day Coast Guard Innovation Exposition. The purpose of the Forum was to foster focused exploration of potential technological solutions to the evolving MDA requirements and address the capabilities needed to meet those requirements. Attendees participated in in-depth discussions regarding MDA related technological developments with subject matter experts from industry and academic organizations, as well as members of the DHS and the USCG. The RCT Forum commenced with a general session

to acquaint attendees with the current state of MDA requirements, plans, and programs, followed by seven concurrent seminars on the following topics:

- Long range (beyond line of sight (LOS)) sensors
- Short range (LOS) sensors
- Data fusion
- Data mining/anomaly detection (automated tools)
- Display and decision assistance systems
- Total system planning/engineering/integration
- Unconventional platforms (lighter-than-air (LTA), buoys, etc.)

The results of the National MDA Technology Working Group were also briefed as a point of departure for future discussion and research efforts.

10. MISRAD Leadership Summit, February 2005

A Maritime ISR and Detection (MISRAD) Leadership Summit was held at NPS on 23-24 February 2005. Cost estimation was one of the many important topics covered during this event. In response to a high level of interest, the "*Improving Cost Estimates for Advanced Concept Technology Demonstrations*" brief was made available the greater MDSRP community through an online portal. Topics covered in the brief included: objectives and assumptions; why credible cost estimates are important; cost estimating in the acquisition processes; and recommendations.

The brief was presented by Dr. Daniel A. Nussbaum of the NPS Department of Operations Research.

POC: Dr. Daniel Nussbaum (danussba@nps.edu)

11. MDA Executive Interagency Workshop, October 2007

On 25 and 26 October 2007, the MDSRP hosted an executive interagency and industry workshop to review the most pressing issues related to maritime security and achieving MDA vision and goals. Senior executives from DHS, DoD, USCG, Navy

Strategic Studies Group (SSG), the International Maritime Organization (IMO), DOT, the National Oceanographic and Atmospheric Administration (NOAA), industry and the Center for Naval Analyses (CNA) met to highlight outstanding research issues related to achieving goals in MDA and maritime security. The results of this workshop were intended to shape the focus of the CNO's Distinguished Fellows program and maritime defense and security research programs in the National Security Institute.

POC: Jeff Kline (jekline@nps.edu)

C. EXPERIMENTATION

In a symbiotic relationship with applied research and graduate education, experimentation allows at sea and field testing of new concepts, technologies, and procedures. The MDSRP sponsored faculty and student participation in a variety of maritime security experiments across the globe.

1. Coalition Operating Area Surveillance and Targeting System (COASTS)

The goal of the Coalition Operating Area Surveillance and Targeting System (COASTS) project was to create a mobile field test bed environment for research and development, integration, operational testing, and field validation using unmanned aerial vehicles (UAVs), manned and unmanned air/ground/water sensors (i.e. soldiers equipped with handheld technology), and emerging wireless network technologies to display Command and Control information to a local/remote/global or mobile tactical and network operations center (*see Figure 23*).

Figure 23: Coalition Operating Area Surveillance and Targeting System (COASTS)

In 2006 the program name was changed to the Cooperative Operations and Applied Science and Technology Studies (COASTS) as it evolved into a large-scale international field experimentation program to develop and assess leading edge technologies for specific military, peacekeeping and stability operations, law enforcement, and first responder missions. COASTS engaged international and domestic partners at the research and development level through cooperative science and technology field experimentation to investigate and match participant mission needs with integrated command and control, computers, communications, intelligence, surveillance and reconnaissance (C4ISR) solutions in domestic, bilateral and multi-national environments. Since its inception, the COASTS program has been a contributing partner to MDP research at NPS, with students conducting award winning research and participation in exercises Talisman Saber and SEACAT, along with its own field research events. This research allowed U.S. military commands, including NPS, to collaborate with coalition partners and allies to support Global War on Terror (GWOT) objectives and operational and security requirements, using the latest wireless networking technologies, tools, tactics, and techniques. NPS and Thailand were the initial team members that integrated the proposed equipment and technology into a system to facilitate surveillance and monitoring of "areas of interest."

The COASTS program experimented with individual and small unit network-capable communication and threat warning technologies, most of which are commercial-off-the-shelf. The COASTS topology used an open, plug-and-play architecture that is user-configurable. This enabled U.S. and coalition partners to implement a common operating picture – situational awareness – via a self-forming, self-authenticating, autonomous network.

MDP-RG Researchers Reconnect Tsunami Survivors to the World

A survivors' camp and nearby grave registration center/morgue in the Thailand coastal areas hardest hit by the 26 December 2004 tsunami were reconnected to the world only days after the disaster thanks to a fly-in wireless network team from the Naval Postgraduate School. Information Systems Department faculty member and MDP-RG member Brian Steckler headed the Coalition Operating Area Surveillance and Targeting System field experimentation research group that set up wireless networks. This work successfully established internet connectivity between a refugee camp near a resort area two hours north of Phuket, Thailand (Khao Lok), and a Bhuddist Temple repurposed into the grave registration center and morgue in the nearby fishing village of Takua Pa.

The COASTS program directly supported organizing, training, and equipping U.S. military forces and the Thailand Defense Forces in seven principal mission areas: 1) Direct Action; 2) Tactical Reconnaissance; 3) Foreign Internal Defense; 4) Combating Terrorism; 5) Civil Affairs; 6) Counter-proliferation of Weapons of Mass Destruction; and 7) Information Operations.

The program set out to address three primary concerns:

1) Does COASTS provide threat warning information as part of a wireless LAN/WAN?

2) Does COASTS meet performance requirements when deployed to Thailand (ground/jungle scenario - such as the 2500 kilometer Thailand/Myanmar border region)?

3) Does COASTS meet performance requirements when deployed to Singapore (water scenario - such as Straits of Malacca and/or Singapore Straits)?

The COASTS program also provided student thesis, research and development field testing, and exercise program opportunities in the following areas:

- Wireless mesh network and wireless long haul broadband communications
- Enhanced situational awareness and 3D common operational picture
- Advanced ISR systems
- Unmanned vehicles – unmanned surface vehicles (USVs) and maritime mini-UAVs
- Wearable computing devices for maritime interdiction operations (MIO)/ extended maritime interdiction operations (EMIO)
- Handheld biometric devices and biometric reachback
- Handheld chemical, biological, and/or nuclear sensing devices

This experimentation project provided opportunities in the following operational areas of interest:

- MIO/EMIO
- Riverine patrol and security
- Counter-drug smuggling, terrorism operations, and transnational crime
- Improved MDA
- Key project events identified by the research team were:
- Contiguous U.S. field tests every November, January, and March from 2005 to 2009
- Thailand field tests every May and June from 2005 to 2009
- Fleet exercise demonstrations (SEACAT) June 2006-2008
- COBRA GOLD, 2008-2009

The benefits to the warfighter from this experimentation project were many. The multinational information sharing allowed analysis of essential communications channels

and processes. Research into Hastily Formed Networks (HFN) to provide flexibility, durability and scalability in adverse environmental conditions spawned new research projects into this essential use of communications technology in the field (*see report section II:C:3*). Benefits of this project also included real-time, net-centric information management for improved situational awareness at local and remote C2 nodes (target identification, battle damage assessment (BDA), etc.) and expanded warfighter capabilities. Evaluation of consumer off-the-shelf (COTS) technologies within a system-of-systems, security analysis and penetration testing by a Red Cell, and enhanced bi-directional high-bandwidth information sharing for boarding operations were all of additional benefit to the warfighter.

Milestones to fielding capability were identified as: 1) incorporate COASTS-05/06/07 Lessons Learned into COASTS-08 plans; 2) complete a system and subsystem analysis and evaluation for military and law enforcement utility; 3) develop a preliminary CONOPS, TTPs and lessons learned; 4) demonstrate successful employment of real-world high payoff systems and technologies; and 5) conduct operationally focused research with experienced military personnel with a short development-to-testing-to-deployment timeline, approximately one to two years.

Key deliverables each year from 2005 to 2009 were 1) a COASTS Technology Demonstrations to VIPs every year in June, 2) the COASTS After Action and System Evaluation reports (*available upon request*), 3) individual Technology Assessments as part of the After Action Review process, 4) the preliminary CONOPS and TTPs produced and available each year as part of the COASTS team documentation process, and 5) deployment of employment-ready technologies and Fly-Away Kits (FLAKs). These FLAKs were then used in further experimentation with the build-on Hastily Formed Networks (HFNs) project in 2006 and 2007.

Organizations partnering with the MDSRP in this project included: Commander U.S. Pacific Fleet (COMPACFLT) and USPACOM, Office of the Secretary of Defense for Homeland Defense, USCG, ONR Navy Reserve Program, Royal Thai Armed Forces (RTArF). Commercial contractors and vendors included Cisco Systems, Mercury Data Systems, Rajant Corporation, CyberDefense Systems, Redline Communications, and

INTER-4. The NPS COASTS team was led by Research Associate James Ehlert and Lecturer Ed Fisher.

POC: Research Associate James Ehlert (jfehlert@nps.edu)

a. COASTS 2008

In FY08, the COASTS international field experimentation team, consisting of over thirty members representing NPS faculty and students, ONR reservists, and industry representatives, completed a successful two-week field experimentation in partnership with the RTAF at Ao Manao Air Base in South-Central Thailand. "The COASTS 2008 International Field Experimentation Team is experiencing wonderful R&D synergy with the Royal Thai Armed Forces via its veteran partners such as the Defense Science and Technology Organization and the Royal Thai Air Force, but also with the inclusion of several new partners such as the Royal Thai Navy Research and Development Office, the Royal Thai Navy surface fleet, and the Royal Thai Navy SEALS," said NPS Information Sciences Research Associate James Ehlert, COASTS Program Manager. "The opportunity for collaborative project and inter-operability exchange between the Royal Thai Armed Forces and the Naval Postgraduate School has never been better."

Figure 24. ENS Chris McCook and the Thai-US Security Team apprehends the scenario RED team and collects biometrics data

The completed Field Experiment (FEX) IV at the Royal Thai Air Force (RTAF) Base in Ao Manao, Prachuap Khiri Khan province, brought the U.S.-based

COASTS infrastructure employed in FEXs I, II and III at Camp Roberts, California, into the challenging environment of Central Thailand. FEX-IV also integrated the COASTS Thai partners including officers and enlisted personnel from the RTAF and the Royal Thai Navy (RTN) (*see Figure 24*). FEX-IV featured the first time integration of an RTN Fast Patrol Craft in the COASTS architecture. The COASTS-08 Scenario features a combined Thai-US Team operating jointly in three scenario phases: (1) a *Humanitarian Assistance/ Disaster Relief* phase, (2) a *Force Protection/ Base Security* phase, and (3) an *Oil Pipeline Security/ Maritime Interdiction Operations* phase.

In the first phase, a combined Thai/U.S. force responded to a simulated tsunami event in southern Thailand, much like the actual 2006 tsunami disaster. Ground forces, manned and unmanned air assets and the RTN patrol craft arrived on scene to provide real-time C4ISR capabilities via a hastily formed network. In the second phase, a red-team attack on an Ao Manao Air Base, COASTS sensors detected the attack and provided situation awareness to local and remote command nodes which prompted the deployment of combined Thai/ U.S. security teams. These sensors were all connected via the COASTS network consisting of a variety of cutting-edge wireless communications technologies protected by advanced network security systems.

In the third phase, an attack on a simulated oil pipeline, the COASTS sensors detected the attack allowing command authorities to order a combined Thai/U.S. special operations force to be launched from the RTN patrol craft resulting in apprehension of the terrorists before the pipeline could be damaged. The RTN patrol craft then conducted a boarding of the attacking Red Team vessel launching the attack while transmitting video and biometrics data of the boarding operations back in real-time on the COASTS network.

Figure 25. Royal Thai Air Force airman's biometrics collected

In Phases 2 and 3, all apprehended "suspects" had their biometrics data collected, including fingerprints, iris and face scans (*see Figure 25*), and sent in real time to the Biometrics Fusion Center (BFC) in the U.S. Biometrics matches were made by the BFC against previously loaded data resulting in positive identification of high value suspects in less than five minutes from collection to having the answer on scene. "The COASTS surveillance network was able to provide immediate situation awareness to remote decision makers over an area which previously had no surveillance coverage," said CAPT Paul Marshall who heads the ONR Reserve Team. "A remarkable aspect of this capability was that it was set up from scratch in days. The hastily formed, deployable aspect of the C4ISR architecture makes it applicable to modern warfare scenarios." Air Vice Marshall Wanchai from the Thai Defense Science and Technology Office (DSTO) added, "The COASTS program is just the right fit and size for the Defense Science & Technology Office to participate and to undertake joint research efforts. It has a successful blend of commercial and military applications without the overhead of other international engagements. We are very excited to expand our involvement for FEX V and for COASTS 2009."

POC: Research Associate James Ehlert (jfehlert@nps.edu)

b. COASTS 2009

December 2008 was an interesting month especially in light of the protest by the People's Alliance for Democracy (PAD) at the Bangkok International Airport and the subsequent closure of the Bangkok International Airport itself. The Scenario

Development Conference was postponed until 16-20 February, and ultimately combined with the Initial Planning Conference. Nonetheless, COASTS team members happened to be in the Kingdom of Thailand on leave/vacation an managed to meet and conduct business with US and Thai counterparts. In addition, the "in-country" team members visited the Thai police checkpoint – Nakhon Sawan – and adjusted the upcoming installation of the License Plate Recognition (LPR) system scheduled for a February 2009 installation. Also, the COASTS program continued to seek an operational sponsor and to that end had initial discussions with the U.S. Marine Forces Pacific (MARFORPAC) Experimentation Center (MEC) to potentially move the COASTS headquarters to Oahu, Hawaii, on 1 August 2009 in alignment with MARFORPAC research and development goals for the Pacific Theater.

The Commanding Officer of the USCG Monterey Bay approved a COASTS multi-system installation to function as a "live" test-bed for further experimentation and research and development efforts. This installation includes the Kestrel Technology Group license plate recognition system, the Lockheed Martin facial recognition system, and the Savi Inc. Radio Frequency Identification (RFID) system, all scheduled for an early January deployment and ultimate integration with the COASTS global network.

POC: Research Associate James Ehlert (jfehlert@nps.edu)

c. Consolidation with U.S. Marine Forces Pacific (MARFORPAC) Experimentation Center (MEC)

In mid 2009 it became apparent that the programmatic objectives of the MEC and COASTS had converged and aligned to the point where a consolidation of the two efforts was warranted. This transition ultimately provided greater value to program participants by: 1) focusing resources on technologies to support the warfighter, theater security cooperation, and science and technology objectives; and 2) aligning all PACOM experimentation efforts to leverage reduce resource costs, and provide increased return on investments. USPACOM approved the initiation of a new experimentation test-bed called the CRIMSON exercise series. CRIMSON VIPER was the first iteration of this new field experimentation venue, and occurred in Thailand in July 2009. This experimentation

served as a gateway for technology insertion into exercise COBRA GOLD. The executive agent for CRIMSON VIPER was the MEC and the event supported both USPACOM and RTArF science and technology requirements. CRIMSON VIPER experiments and associate technologies were dictated by the results of the exercise COBRA GOL Technology Insertion Workshop process. All candidate technologies are evaluated and assessed in CRIMSON VIPER at one of three levels:

1) ***Static Display*** – non- operational showcasing of Systems
2) ***Demonstration*** – an event where the primary purpose is to demonstrate an emerging technology with no formal assessment conducted
3) ***Assessment*** – an event where a range of evaluation is being conducted

These categories align directly with, and in all cases support, exercise COBRA GOLD experimentation initiatives. CRIMSON VIPER benefits from the MEC/COASTS model synergies and increases the delivery of short development cycle capabilities and solutions driven by the warfighting community. This transformation of the COASTS program provides even greater value to NPS and U.S. program participants while serving to focus resources on the best technologies with the most chance of supporting the warfighter.

POC: Research Associate James Ehlert (jfehlert@nps.edu)

2. Field Information Support Tool (FISTS)

The Field Information Support Tool (FIST) is a field based collection system using COTS smart phones, customized software, and a robust information management backend known as *FusionPortal* with a deployable sensor fusion system known as *FusionView* that enables information to flow from the point of capture to an analyst in near real-time regardless of location or physical proximity (*see Figure 26*).

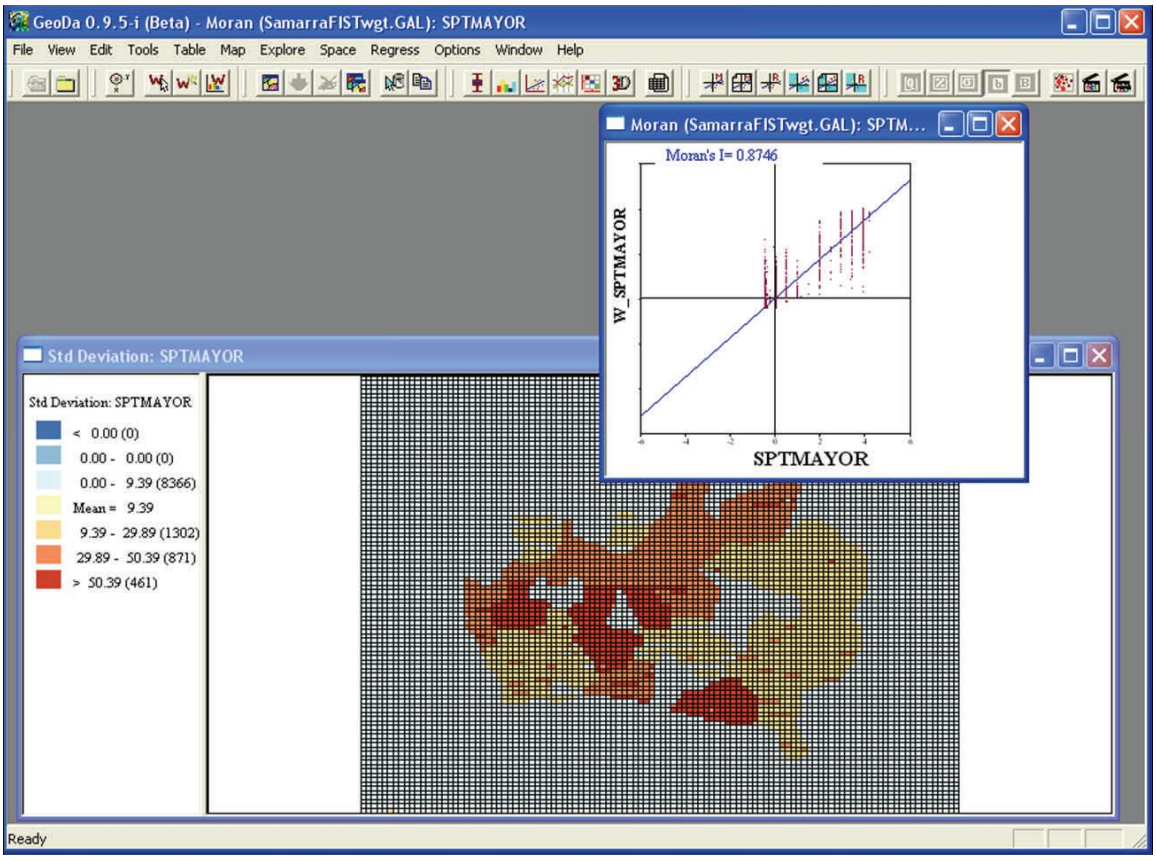

Figure 26. Field information support tool (FIST) Fusion View example

The concept of FIST originated with Capt Carrick Longley, USMC, and CW3 Chad Machiela, USA, while both were students at NPS. FIST is designed to operate in a variety of environments and supports a variety of mission sets such as counterinsurgency operations (COIN), counter-narcotics missions (CN), and humanitarian assistance and disaster response (HA/DR).

FIST is divided into three separate components that comprise the system. The field collection tool is known simply as *Gather*, the web-based information management portal is known as *FusionPortal*, and the analysis, sensor fusion and visualization system is known as *FusionView*. The overarching principle of FIST is the development of a user-friendly data collection tool that utilizes automated information systems to enable unstructured data to be collected, processed, and structured for analysis and visualization in a variety of analytic packages. *FusionView* enables real-time integration of disparate sensor systems that provides a powerful common operating picture critical for today's decision makers. *FusionPortal* allows for data to be exported and analyzed using

geospatial, geo-statistical, temporal, link, and social network analysis in addition to enabling the exchange of information with external databases such as the All Partners Area Network (APAN).

Figure 27. CARAT 2010 team aboard the HTMS Naresuan, Sattahip Naval Base, Thailand

In FY10 the NPS FIST team deployed to Sattahip Naval Base in Thailand from 13-21 May to participate in exercise Cooperation and Readiness Afloat Training (CARAT) 2010 (*see Figure 27*). The NPS team consisted of Mr. James Ehlert, Mr. Ed Fisher, and Capt Carrick Longley. Additionally, Mr. Ivan Cardenas of Kestrel Technology Group and Mr. Cyril Berg, Mr. Paul Trist, and Mr. Aaron Aamold of AeroVironment were also integrated with the NPS team. The combined team was tasked with demonstrating smartphone data management, information fusion and UAV technology respectively. Using the AeroVironment Puma AE unmanned aerial vehicle (UAV), the NPS team was able to demonstrate an integrated HA/DR and reconnaissance platform using low cost communications solutions. The PUMA AE was also combined with UHF data radios for communication relay capability trials. The trials are a first stage evaluation for meeting the requirements being developed by 31st MEU under III-MEF for OTH VHF/UHF communications relays using expeditiously deployed UAV platforms for extended periods. The OTH horizon trials were successfully accomplished as well as demonstration of the strong tactical capabilities of the system. Land and sea launch and recovery operations of the relay equipped aircraft were demonstrated in various combinations as well as communications relay and site reconnaissance support of the

main exercise event, the amphibious landing. In addition to the tests, several flag officers from the Royal Thai Armed Forces (RTArF) were briefed on FIST and its application for Humanitarian Assistance / Disaster Response (HA/DR). Rear Admiral Tyson of CTF-73 was also briefed. FIST was well received by all and invitations from the RTArF for future FIST demonstrations are forthcoming.

Other FIST initiatives include FIST Armed Forces of the Philippines (FIST AFP), FIST Nepal (FIST NEP), FIST Singapore (FIST SIN), FIST Pandemic Influenza (FIST PI), FIST U.S. Census Bureau, and FIST USAID. Further information on any and all of these initiatives is available upon request. Seeded with MDSRP resources, current project sponsors include USPACOM, Special Operations Command Pacific (SOCPAC), and Counter-Narcoterrorism Technology Program Office. Project partners include a wide range of representatives from international government, academia, and industry.

POC: Research Associate James Ehlert (jfehlert@nps.edu)

3. Hastily Formed Network Experiments and Humanitarian Missions

Immediately after the December 2004 tsunami off Banda Aceh, NPS deployed faculty and students on the coastline of Thailand with Information and Communications Technology (ICT) equipment in support of the international response to the devastating tsunami. The NPS Hastily Formed Networks (HFN) team has also deployed with equipment and expertise to support DoD in Hurricane Katrina in 2005, and most recently the Haiti earthquake of 2010. They have also supported major Pacific region exercises including COBRA GOLD and PACFIC ENDEAVOR (*see Figure 28*).

Figure 28: Hastily Formed Networks humanitarian assistance work

The NPS HFN research group uses real-world events and exercises like these to show the art of the possible with rapidly deployed communications and continues to be innovative leveraging very portable/mobile ICT and information sharing applications in HA/DR missions.

Current NPS research now includes integration of push-to-talk radio communications, fossil fuel alternative power sources (solar, wind, etc.), and viable software applications for HR/DR efforts. Objectives of this HFN experimentation were many-fold, but primarily centered around demonstrating and operating HFNs portable and mobile technologies:

- 802.11 WiFi, 802.16 WiMAX, Broadband VSAT satellite internet reachback, and Voice Over IP
- Communications technologies integrated as prototypes to create COMMUNICATIONS, VISUALIZATION, ALTERNATE POWER and NETWORK OPERATION CENTER Fly-away Kits (FLAKs)

Benefits to operations articulated by the project team were numerous. NPS deployed HFNs gear and FLAKs in several locations while their host ships performed humanitarian missions. The project provided opportunity to both learn from and demonstrate the utility of challenges and options possible with HFNs in remote areas of

the world. Patient tracking system experiments with the Defense Manpower Data Center (DMDC)/OSD were also of operational benefit.

Milestones to fielding capability identified by the research team were the setup of similar NPS support for a planned USS FT. MCHENRY outreach mission to Western Africa (Gulf of Guinea), and NPS coordination with NETWARCOM, Fleet Forces Command, and others on frequency spectrum issues with gear radiating from the ship at these foreign ports. Key deliverables were a field demonstration and CONOPS.

Sponsored in part by the Assistant Secretary of Defense for Networks and Information Integration (ASD(NII)), total funds required for this NPS HFN work was well over $2 M between FY's 2007 and 2011. Primary research sponsors have been DHS and the Office of the Secretary of Defense with student participation sponsored by the MDSRP. This experimentation project was led by NPS Professor Brian Steckler.

POC: Professor Brian Steckler (steckler@nps.edu)

4. Maritime Interdiction Operations (MIO)

The overall goal of these studies was to provide planners, commanders and field personnel involved in marine interdiction operations and other related missions with guidance on how the environment affects operations. All physical environmental effects such as weather, visibility and sea state were considered, with emphasis on atmospheric effects on target detection (both radar and visible), communications systems, jamming systems and weapon performance.

The maritime interdiction operation (MIO) projects are ongoing, and have involved many efforts over time. A representative sample of MIO efforts supported in full or part by the MDSRP are included in this report. More information on any and all MIO projects are available upon request.

POC: Dr. Alex Bordetsky (abordets@nps.edu)

a. MIO 08-2

The MIO 08-2 experiment introduced several unique new elements, including tagging and global monitoring of suspect vehicle, multiple small drive-by

detection and data sharing between the boarding party searching large vessel under the deck and Riverine area stand-of detection.

Figure 29. MIO 08-2 receiving SA tracks, video, and biometrics data feeds from the overseas sites (Sweden)

The monitoring phase unfolded in Europe. It began with tagging a "suspicious" car at the simulated border control check point in the Bavarian Alps, including biometrics identification (*see Figure 29*) and nuclear radiation source detection on board the vehicle. The original goal was for the expert teams at Lawrence Livermore National Lab (LLNL) to immediately engage in the analysis of source/crew data interactions and develop rapid situational understanding by means of real-time collaboration with the check point cell, comprised of the small command post at the University of Bundeswhr (UoB), Munich, and the mobile check point 30 mi South of Munich in the Alpine area.

The critical new goal was to tag the vehicle and keep monitoring its movement through Germany to Poland and on to the ferry heading towards Sweden. The Swedish Naval Warfare Center (SNWC) MIO team in Sweden and the command post in Munich would be addressing the challenge of continuing monitoring, by resolving the difficulties via the TNT MIO Operations Center at the NPS CENETIX in Monterey. The LLNL group was able to communicate data with the watch officer in Livermore and communicate the results back to the check point. The UoB command post successfully used NPS situational awareness tools for monitoring, while the NSWC was also combining it with the SNWC (Sweden)/KOCKUMS Blue Force tracker.

Figure 30. MIO 08-2 small craft detection and interdiction in progress

The objective for the interdiction and search phase was to explore the feasibility and major constraints associated with collaboration, data sharing between boarding parties engaged and the ability of command centers to come up with the scale of threat imposed by multiple small craft penetrating the metropolitan area (*see Figure 30*). Combined self-aligning orthogonal frequency division multiplexing (SAOFDM) and the wave relay network delivered drive-by detection of eight suspect vessels simultaneously.

In general, the MIO 08-2 appeared to be a significant step forward. It produced vital results for tagging and monitoring, allowed the most successful identification of drive-by CONOPS, demonstrated excellent performance of wave relay platform and satellite point-to-point reach back solutions (Swe-Dish, Tachyon), produced good results at different commands and provided for expert site collaboration.

POC: Dr. Alex Bordetsky (abordets@nps.edu)

b. MIO 08-4

The MIO 08-4 experiment was a significant next step in evaluating the use of networks, advanced sensors, and collaborative technology for rapid MIO, including the ability to search for radiation sources, set up ship-to-ship and ship-to-shore communications while maintaining network connectivity with C2 organizations, and regional-scale collaboration. The specific goal for the MIO 08-4 experiment was to explore new sensor, networking, and situational awareness solutions for interdicting, searching, tagging, and monitoring large vessel as well as small craft, threatening the security of the coastal metropolitan areas on the scale of the radiological threat in the Port

of New York and New Jersey and subsequent events in the Riverine area of Hampton Roads, Virginia (*see Figure 31*).

Figure 31. MIO 08-4 dislocation of command post and target ship at berth 17 (Phase I, Day 1) and two small target vessels (Phase II, Day 2)

The situational awareness focus of the experiment was to explore the requirements for broad interagency collaboration and data sharing using the capabilities of the Port Authority of New York and New Jersey (PANYNJ) joint C2 Joint Analysis Center (JAC) feedback, and two-way data sharing with the Riverine Area of operation. Correspondingly, the TNT MIO 08-4 experiment was structured as four day event sequence. During the first two days interdiction and threat response activities were taking place in the Port of New York and New Jersey area with complementary data feeds from the early warning sites in Europe. Upon interdicting, searching, and tagging the suspect small vessel, the experiment activities for the next two days were moved to the Riverine area of operation nearby Ft. Eustis at Hampton Roads, Virginia

POC: Dr. Alex Bordetsky (abordets@nps.edu)

b. TNT MIO, 2010

During FY10, Dr. Guest, in the role of Principal Investigator, participated in two TNT MIO experiments. These were a continuation of a series of field programs directed by Dr. Alex Bordetsky, NPS. The principal investigator provided weather

forecasts each morning of these operations, keying on those features that were most likely to affect operations. Major weather impacts were high winds and rough sea state conditions during the April, 2010 field program in the estuary near Ft. Eustis, VA and a series of thunderstorms which affected operations for the program in Germany in June.

In addition to providing traditional weather guidance for TNT operations, in FY 2010 the principal investigator also performed studies of how the environment affects target detection in harbor areas using both radio (radar) and visible and IR imaging systems. Most notable was the performance of the Panama City *Near Earth Propagation Test* in August, 2009. This experiment involved precise quantification of low level short range radio signals – such as those used to detect mines or triggering devices – in conjunction with detailed measurements of the near-surface atmospheric properties. Although there were significant variations in signal strength it was difficult to relate these to specific environmental factors at very close (73 m) ranges. The most important factors were the elevation of the radio receivers and transmitters. It was found that signal strength was proportional to the fourth power of path elevation, and lower paths were more strongly affected by negative interference from surface reflections.

POC: Dr. Peter Guest (pguest@nps.edu)

c. NPS-LLNL MIO 2011: Searching, Tracking, and Interdicting Cargo Ships and Multiple Small Craft Possessing Nuclear Radiation Threat

MIO 2011 experimentation goals included:

1) The application of USVs to small craft screening and pursuit;
2) Collaboration between U.S. experts and overseas operators on network-controlled choke point setup, drive-by primary and secondary screening, stand-off detection at high-speed pursuit (Singapore, Souda Bay-Greece);
3) The application of UAV and unmanned ground vehicles (UGVs) to the combined search of cargo vessel and small vessel detection via cooperative UAV-UGV (cargo vessel) and USV small craft detection;
4) network-enabled swimmer detection of small craft-sourced threat at the overseas POE (Singapore, Souda Bay); and

5) Ground tracking of illicit material transfer to port security areas in Singapore and U.S. military sites overseas (*see Figure 32*).

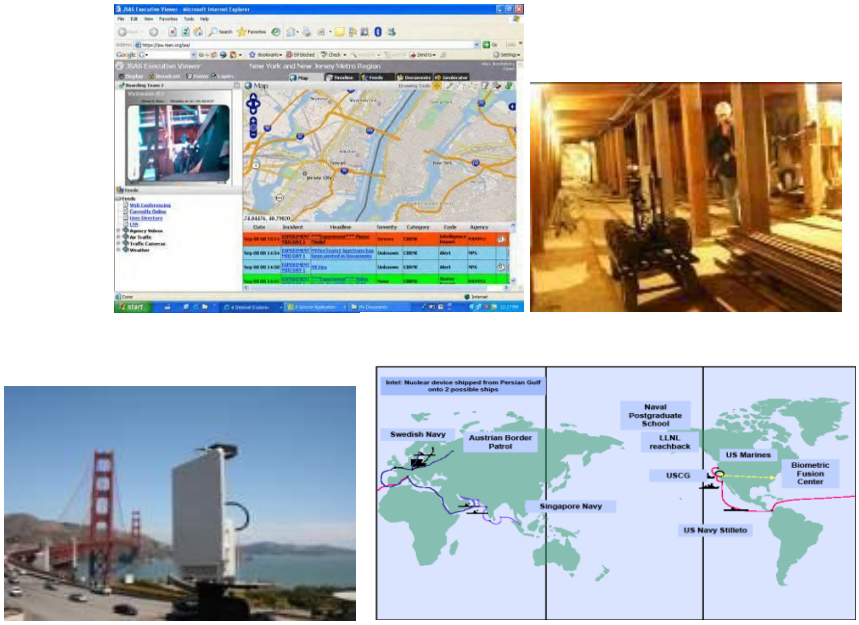

Figure 32. Globally distributed tagging, tracking, and search experimentation

Network Controlled Nuclear Radiation Detection:

- Small craft drive-by detection at high speed
- ARAM – Adaptable Radiation Area Monitor used for Drive-by detection
- Choke point (portal) detection operational model
- Stand-off mesh network-controlled detection
- Multiple small craft search and interdiction
- Network-controlled unmanned surface vessels
- Tactical broadband wireless, cellular, satellite, and UWB network

Figure 33. NPS-LLNL MIO 2011

This series of experiments (*see Figure 33*) is ongoing.

POC: Dr. Alex Bordetsky (abordets@nps.edu)

5. USSOCOM-NPS Field Experimentation (FEX) Cooperative – Maritime Security Component

The key objective of this program was to evaluate the use of networks, advanced sensors, and collaborative technology for rapid MIO, port security, and riverine operations; e.g. for MIO, the ability for a boarding party to rapidly set up ship-to-ship communications that permit them to search for a radiation and explosive sources and collect biometrics while maintaining network connectivity with C2 organizations, and collaborating with remotely located sensor experts, coalition partners, and first responders (*see Figure 34*).

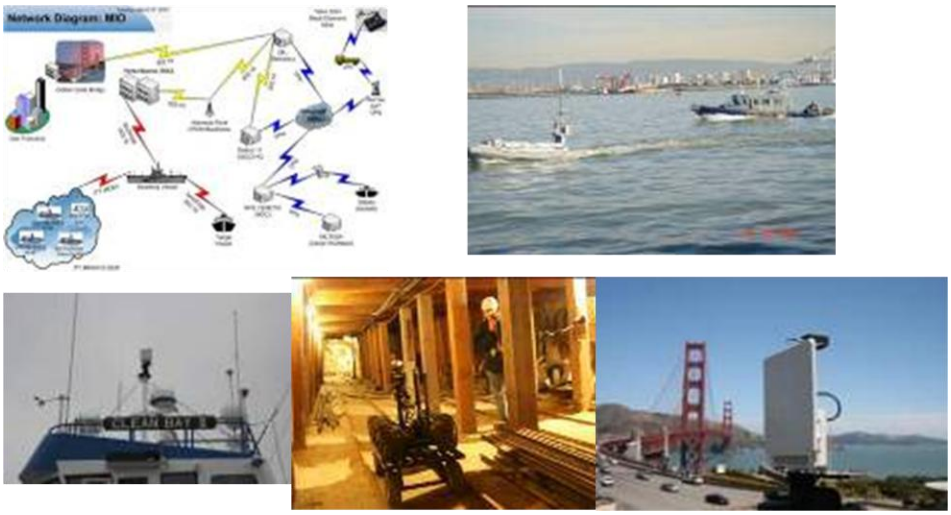

Figure 34. USSOCOM-NPS Field Experimentation Cooperative maritime security component

In partnership with the USSOCOM, NPS conducted the second quarter FY08 FEX during three different time periods: 1) San Clemente Island from 4-6 February 2008; 2) Camp Roberts, CA, Camp Dawson, WV, and Camp Atterbury, Indiana from 23-29 February 2008; and 3) San Francisco Bay area (including a European component from 3-7 March 2008) from 10-13 March 2008. The primary objectives of the FEX Cooperative Program were to maintain and utilize a full spectrum experimentation capability for providing high value assessments to concept development and Component Master Plans, to provide an independent assessment capability to evaluate effectiveness, affordability, and feasibility of future capabilities, and to provide a unique education and research environment for students and faculty at NPS.

Secondary objectives included examining dual-use capabilities for homeland security, stabilization, reconstruction, and disaster relief/humanitarian assistance, and for other government agencies. This ongoing experimentation project accomplishes these objectives by providing a unique field experiment venue quarterly in which innovation and collaboration are encouraged between DoD, government agencies, industry, and universities, and in which Special Operations Force (SOF) operator participation and feedback are utilized. Major focus was placed on network communications, unmanned systems, airspace management and deconfliction, situational awareness, collaborative environments, sensors, biometrics, and human systems integration.

The Camp Roberts/Fort Hunter Liggett/Camp Atterbury/Camp Dawson portion focused on urban and rural terrain whereas the San Francisco Bay/European experiments focus on maritime interdiction operations, port security, and riverine operations. The MDSRP supported faculty and student participation in these experiments. Major emphasis at Camp Roberts was on pre-requirements experimentation and rapid response to USSOCOM Component Command requests. Camp Atterbury emphasis was on SOF/First Responder concepts, training and evaluations of newly available technologies for near-term utilization. Emphasis at Camp Dawson was on untethered biometrics collection and related communications. SOKF-J9 was assigned the lead to conduct leveraged experiments in cooperation with the NPS TNT Field Experimentation Program.

A *Quick-Look Report* that briefly summarizes the most significant results, observations and lessons learned for the major experiment areas of focus was published at the FOUO level of classification. Additionally, each individual system, concept, or area of focus produced a separate *After Action Report* specific to their objectives and results if a more detailed understanding is desired.

Example technologies evaluated included:

- Innovative wireless networks and sensors
- SATCOM on-the-move and orbital ad-hoc networking
- Laser communications
- Drive-by radiation detection
- Projectile-based wireless links
- Networked USVs and UGVs
- Collaboration and decision making
- Situational awareness
- IPv6
- Environmental effects on target detection, communications, and plume dispersion

- Forward deployed biometrics with reach-back

POC: Dr. Alex Bordetsky (abordets@nps.edu)

6. Seaweb subsurface sensor network for port surveillance and maritime domain awareness

Our national economy and domestic security depend on commerce through our seaports. However, port environments are difficult to monitor and are hence inherently vulnerable. Seaweb acoustic communications are currently enabling distributed anti-submarine warfare (ASW) and maritime sensor networks. The research team hypothesizes that Seaweb sensor networks are well suited for operations in ports and port approaches. Autonomous, distributed, underwater sensors measure environmental parameters and detect surface vessels and subsurface intruders (*see Figure 35*). Seaweb acoustic communications enable real-time, wireless data telemetry and C2.

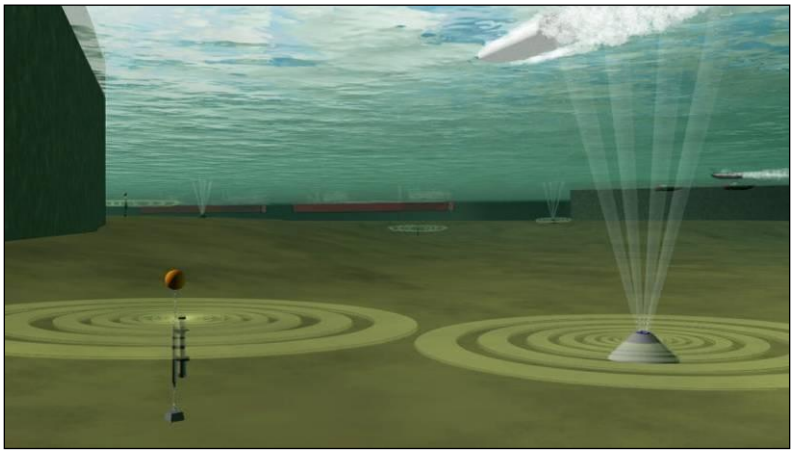

Figure 35. Seaweb's autonomous, distributed, underwater sensors detecting surface vessel

In FY08, the MDSRP Seaweb project established a working arrangement with the Port of Long Beach and demonstrated through-water acoustic communications in the inner port basin. The inner basin network reached through multiple underwater repeater nodes to a police boat positioned in the outer basin. The success of this initial testing motivated conceptualization of networking concepts applicable to shallow port environments (*see Figure 36*).

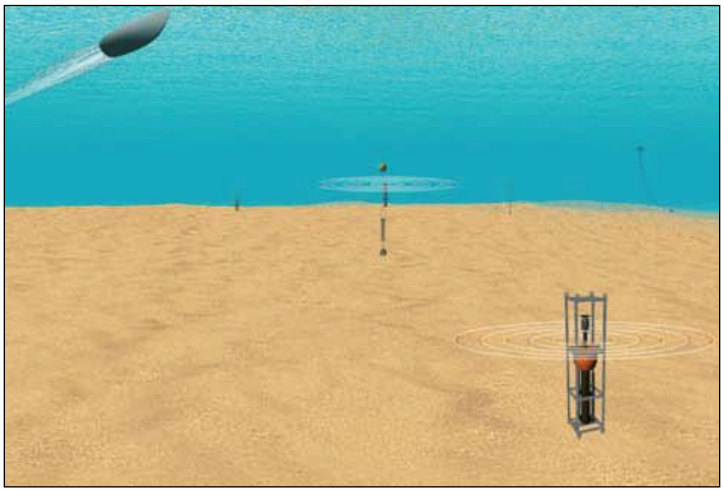

Figure 36. Underwater networked acoustic sensor on the seabed (*foreground*) detect the passage of a surface vessel, and distributed network nodes (*background*) including a Racom gateway buoy provide for near-real-time exfiltration of contact reports.

In FY09, the MDSRP Seaweb project led a coalition of academic and government partners to deploy an acoustic network in San Francisco Bay. The goal of SF Bayweb was to field a wireless underwater sensor and communications network within a major U.S. port having adverse environmental acoustic conditions. The Navy successfully demonstrated Seaweb networking in the Port of Long Beach, CA in 2008 with benign environmental conditions. The San Francisco Bay offered a more challenging environment with heavy shipping traffic, strong currents, and significant sediment transport. During the SF Bayweb experiment, a Seaweb communications network delivered environmental sensor data in near-real-time from the subsurface domain to a shore-based server. These ocean data served the oceanographic community while simultaneously supporting analysis of Seaweb communications performance. SF Bayweb 2009 was a pilot demonstration of a scalable Seaweb network architecture, with the longer-term goal of fielding larger more complex networks, more sophisticated oceanographic and surveillance sensors, and integration with above-water sensors and systems.

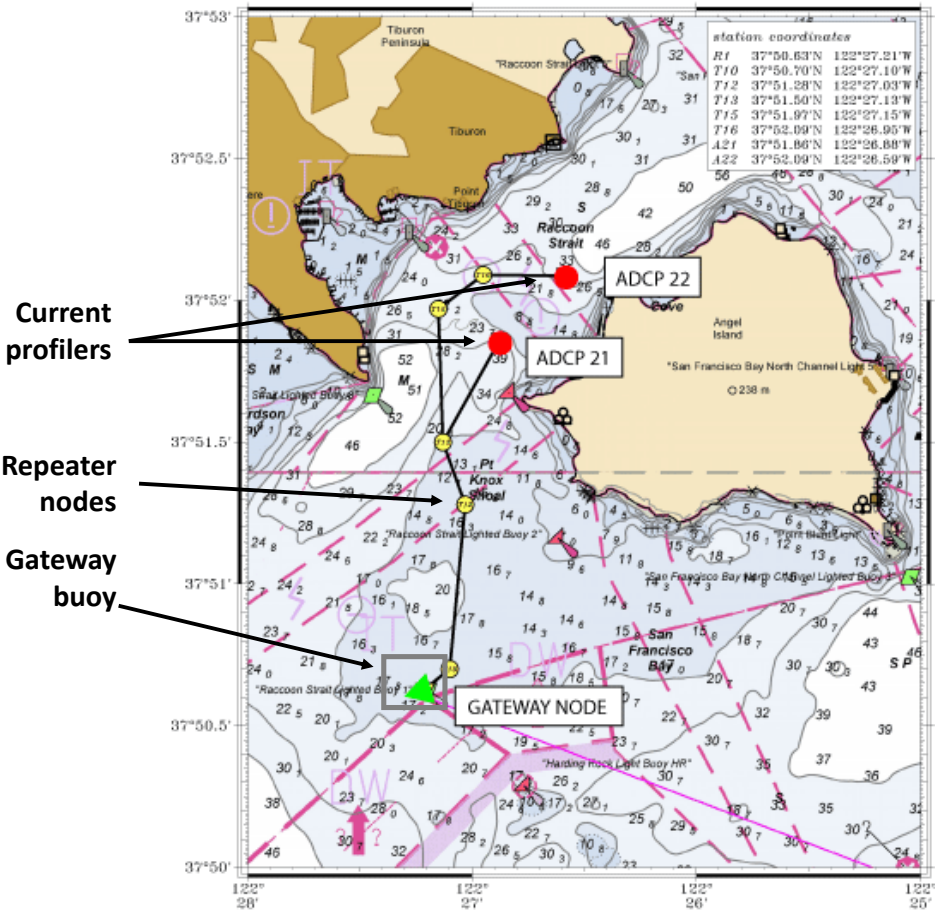

Figure 37. The SF Bayweb 2009 network telemetered data from two ADCP current profilers to a Racom gateway node integrated on a USCG navigation buoy.

SF Bayweb 2009 occurred in the vicinity of Angel Island, in the San Francisco Bay. Two Acoustic Doppler Current Profiler (ADCP) sensors were deployed to measure currents in this area. A Seaweb network composed of five telesonar repeater nodes and one radio/acoustic communications (Racom) gateway node telemetered the environmental measurement data from the undersea sensors to a gateway node (*see Figure 37*). The gateway node provided the link between the land site via cellular telephone modem, and the underwater domain via telesonar modem. The gateway node was a USCG buoy modified with a Seaweb Racom kit (*see Figure 38*).

Figure 38. A Racom gateway kit with telesonar acoustic modem and cellular telephone modem implemented on a USCG navigation buoy in San Francisco Bay with logistical support by USCG cutter GEORGE COBB.

The components of an oceanographic sensor network well suited for San Francisco Bay were developed and demonstrated. SF Bayweb experiences indicate that a surveillance network in San Francisco Bay is indeed feasible. It is recommended that the equipment developed for these experiments be redeployed in San Francisco Bay at a future opportunity with a more ambitious collection of sensor nodes beyond the two ADCPs that were included in Bayweb 2009.

The following organizations participated in the NPS-led SF Bayweb 2009 experiments:

- NPS
- SPAWAR Systems Center Pacific, San Diego
- USCG District 11, Yerba Buena CA
- San Francisco State University (SFSU) – Romberg Tiburon Center for Environmental Studies

- University of California, Berkeley
- Central and Northern California Ocean Observing System (CeNCOOS), Moss Landing CA
- Monterey Bay Aquarium Research Institute (MBARI), Moss Landing CA
- University of California, Davis – Bodega Marine Lab, Bodega CA

In FY10, NPS was prepared to implement and deploy a true maritime surveillance network. With funding provided by the ONR Operational Adaptation exercise the team fielded a Seaweb network with underwater passive acoustic directional sensors in the Intracoastal Waterway at Morehead City, North Carolina, on the U.S. eastern seaboard (*see Figure 39*).

Figure 39. Exercise scenario site (Intracoastal Waterway at Morehead City, North Carolina) involves protection of a high-value port facility (blue) against maritime threats (red).

The experiment objective was to demonstrate capability for first-alert protection of a high-value port facility against asymmetric threats that intelligence sources indicate are arriving via watercraft. Battery-powered acoustic sensors (*see Figure 40*) were rapidly deployed at widely separated chokepoint locations in shallow 5-10 meter water.

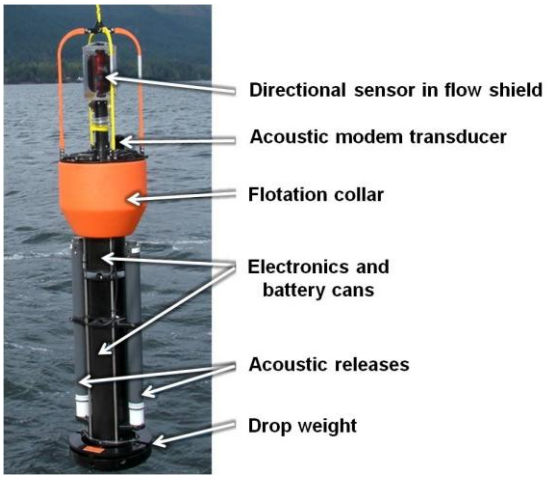

Figure 40. The directional acoustic sensor node is deployed on the seabed at a strategic location.

These sensors autonomously detect the passage of a maritime vessel and generate a contact report indicating time, location and heading of the target. Seaweb through-water acoustic communications delivered the contact report via a scalable wide-area underwater network including multiple acoustic repeater nodes and a Racom gateway buoy. The Racom gateway telemetered the contact report via Iridium satellite communications to an ashore command center with low latency (*see Figure 41*). The in situ acoustic detection was corroborated using shore-based video surveillance to classify the contact as friendly or actionable.

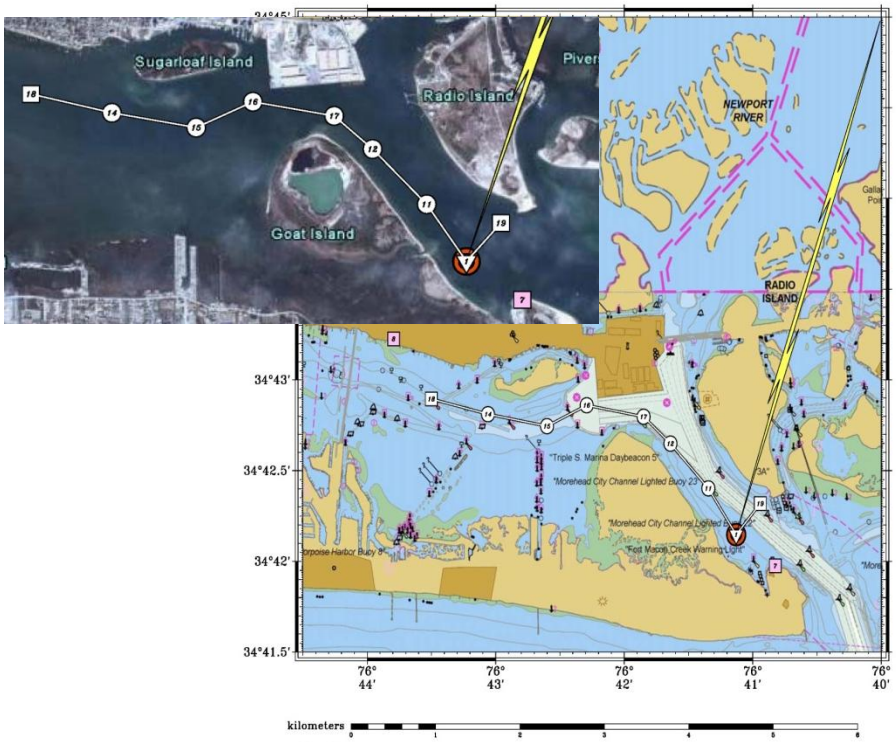

Figure 41. Navigation chart of the Port of Morehead City showing deployed Seaweb network of two sensor nodes (white square symbols), six telesonar repeater nodes (white circles) and one Racom gateway node with Iridium link (*aerial satellite view overlaid at top*).

Statistical analysis of the target opportunities during the three test events shows that the acoustic sensors perform well against targets having closest point of approach (CPA) within 200 meters. Within this range, the probability of detection is Pd = 0.97 (*see Figure 42*). The time required to report the surveillance contact is typically less than two minutes, well within the five minutes required to act upon the alert message. Occasionally the reporting latency is protracted because of a communications failure in the underwater network requiring retransmission. Seaweb successfully resolved these failures using a built-in automatic repeat request (ARQ) protocol. Analysis of recorded data revealed that the sensors begin to track contacts at ranges significantly greater than the CPA ranges. This is a significant result given the shallow-water environment and adverse acoustic conditions.

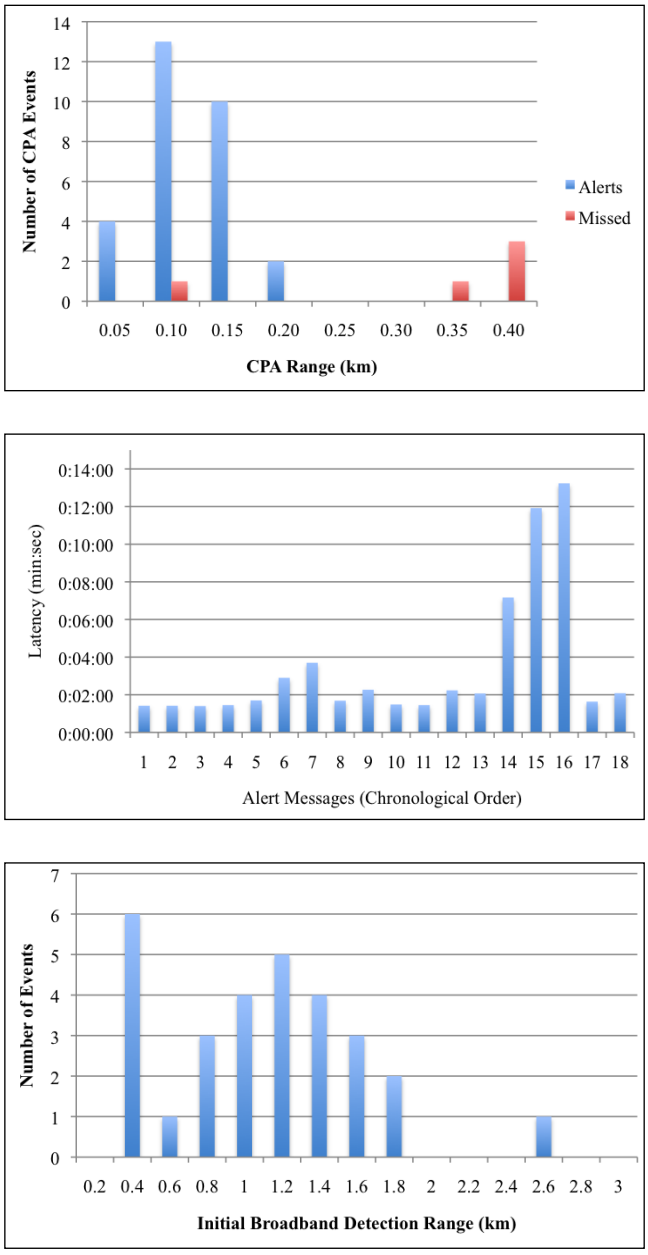

Figure 42. Statistical analysis of the Seaweb target opportunities; CPA range/events (*top*), alert reporting times (*middle*), and contacts (*bottom*)

At the end of January 2009, NPS Seaweb lead Joe Rice chaired a session on unmanned sensors at a U.S.-France bilateral MDA working group convening at the Pentagon Conference Center in Washington DC. In 2009, NPS Seaweb networking integrated autonomous ASW sensors from the U.S., Norway, and Canada operating against a cooperative diesel-electric submarine. The NPS Seaweb project has received an

increasing amount of support as the project evolves and succeeds. The Seaweb project is ongoing, and will continue on past the close of the MDSRP

POC: Professor Joe Rice (jarice@nps.edu)

7. Distributed Information Systems Experimentation (DISE)

The overall objective of the Distributed Information Systems Experimentation (DISE) program is to plan and execute large-scale experimentation of new technologies and tactics to support the joint warfighter.

DISE group thesis research has included MDSRP related topics such as:

1) Examining the effects of placing new and emerging technologies developed in Spiral-1 onto legacy systems and how the U.S. Navy as an organization will either absorb these technologies or make multidimensional changes to enhance the process of achieving MDA, and

2) Examining the impact of improved extended maritime interdiction operations (EMIO) technology designed to bridge together EMIO technology designed to bridge data with intelligence collected during EMIO and improve maritime domain decision making in terms of speed and quality and thus improve end user's situational awareness.

For this latter thesis effort, the DISE group used the construct of Business Process Re-Engineering (BPR) to frame the analysis and to provide focus in the data collection. We also examined the changes to the present EMIO process by developing and implementing an organizational simulation using POWER 2.0. Our results indicate that when improved Spiral-1 EMIO technologies, which significantly decrease the amount of time it takes to fuse collected boarding data into intelligence systems, are combined with a redesign of the EMIO organization, a qualitative improvement toward accomplishing the overall process can be achieved. The current process requires 35 hours. Yet, with the revised technological and proposed organizational changes, the same process can be achieved in f i v e hours, thus achieving the SECNAV vision to streamline and improve maritime operations. This thesis went on to win the Distinguished Thesis Award in 2009.

Key initiatives of this group have included:

- Fleet Battle Experiments E - K
- Trident Warrior Sea Trials 03 to 12
    - Ku band Limited Objective Experiment
- Empire Challenge 05 to 11
    - Joint Battlespace Awareness Intelligence, Surveillance, and Reconnaissance Integration Capability (JBAIIC)
    - Tasking, Processing, Exploitation, and Dissemination (TPED) Management
    - Biometrics Analysis
    - Extended Awareness II, III , 06-1, 2
- MDA
- Joint Multi-Mission Electro-Optical System (JMMES)
    - JCTD OTA
- FORCEnet Innovation Research Enterprise (FIRE)
    - Recently awarded a DON/ CIO award for excellence
    - Developed by DISE to support experimentation planning, management, and analysis.
- Joint Intelligence Interoperability Board (JIIB) System Baseline Assessment (JSBA) for 2004 and 2006-2009
- Hull Search Remotely Operated Vehicle (HSROV)
- Science Advisor to C3F

Current thesis research has begun to explore how weather data and track information can be used in conjunction with other technologies to detect anomalies in the behavior of commercial shipping – thus providing increased identification of vessels of

interest (VOI). DISE research group theses efforts are supported by NPS Research Associate Professor Douglas J. MacKinnon These aligned independent projects received student labor and travel support from MDSRP.

Key sponsorship for DISE group projects has come from NAVNETWARCOM, JFCOM, OSD, OPNAV, NAVAIR PMA 263 & 264D, PEO C4I, US Pacific Fleet, COMNAVAIRPAC, DIA, SPAWAR and the MDSRP.

POC: Dr. Doug MacKinnon (djmackin@nps.edu)

a. Maritime Domain Awareness: Spiral 1 Metrics

This effort of the DISE Research Group involved installation of an overarching concept, processes, procedures, technology, and other system elements is a multi-dimensional decision making problem, which requires definition of measures and metrics by which acquisition of these system elements can be understood, compared, and measured for system performance. However, understanding these system components and the means by which they will be understood, compared, and measured has not been the subject of specific definition. The purpose of this project was to specify measures and metrics that contribute to decision making and continued evolution of MDA system elements that contribute within the GWOT, and are also consistent with DoD, JCIDS, experimentation and acquisition program needs.

With the full project title of "*Definition of Metrics for Maritime Domain Awareness (MDA) and Global War on Terror (GWOT)*," this experimentation project grew out of Dr. Gallup's earlier research work for MDSRP in this topic area. This effort was conducted in parallel with an ongoing MDA study to determine current practices for MDA across Fleets, resulting in proposed improvements for an MDA Spiral-1 prototype. The intent was to use measure and metrics defined in this work to assess Spiral-1 capabilities (*see Figure 43*).

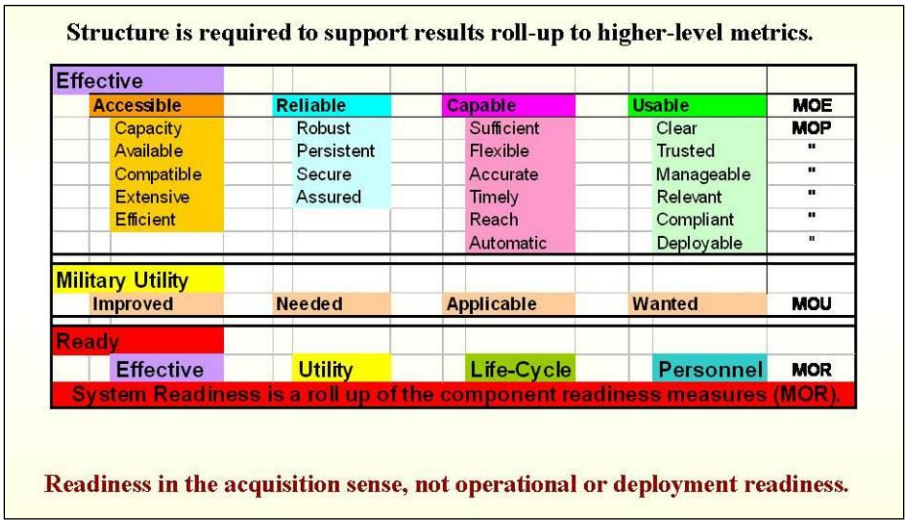

Figure 43. MDA Spiral-1 program metrics structure

Analysis milestones were defined by the lead researcher, and clustered in three distinct phases to align with the concurrent research effort (*see Table 6*):

Table 6. MDA Spiral-1 Metrics analysis milestones and timeline

	TITLE	***TIMELINE***
PHASE 1:	Discovery	JUNE – JULY 2007
PHASE 2:	Process reengineering for improved TTP	AUG – OCT 2007
PHASE 3:	Delivery, validation and feedback/review of proposed Spiral-1 MDA	NOV 2007 – DEC 2008

Funding for this experimentation project came from OPNAV N3/N5 and N6 via PEO C41, and the principal investigator was Dr. Shelly Gallup. The MDSRP supported student involvement in this work. Key deliverables included 1) refined measures and metrics for MDA contribution to the GWOT, and for Spiral-1 capability; 2) a report of field tested use of metrics and measures for military utility; and 3) a report of fit measures and metrics within JCIDS.

POC: Dr. Shelley Gallup (spgallup@nps.edu)

b. Maritime Domain Awareness: Assessment

Acquisition and installation of developed capabilities to meet requirements includes a need to demonstrate the capability within an operational context of sufficient fidelity and variety to justify the cost and effort at integrating these capabilities within a first iteration Sprial-1 MDA system. These capabilities may be organization specific, so that no single venue may be sufficient to the demonstration. This experimentation included the level of effort and project elements to produce a continuum of demonstration, appropriately fit between capability and venue, the collection of necessary data and documentation, and results for reporting levels of performance sought in establishment of the Spiral-1 MDA capability.

Led by NPS principal investigator, Dr. Shelly Gallup, this project integrated efforts across MDA working groups brought together in operational testing under a consistent experiment design process that included standard metrics developed for MDA analysis of capabilities.

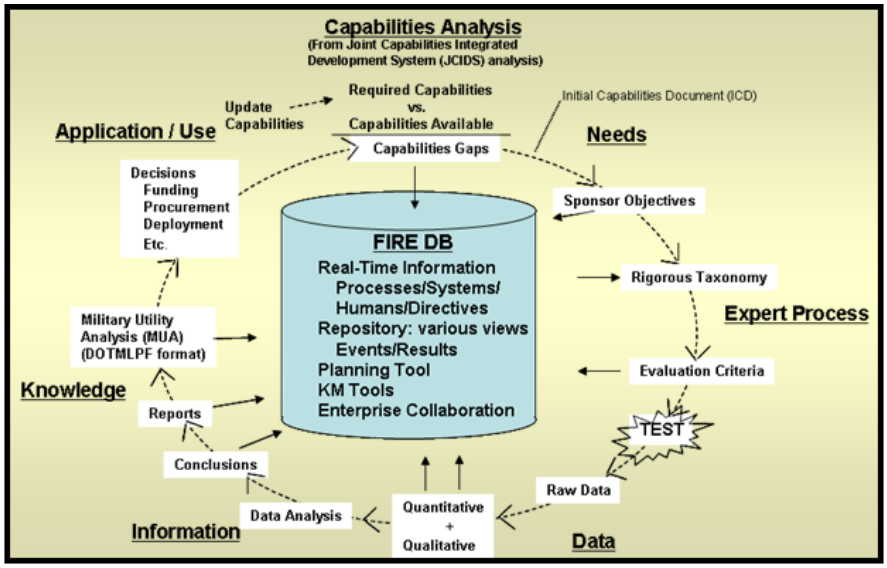

Figure 44. Joint Capabilities Integrated Development System (JCIDS) capabilities analysis applied to MDA assessment

The objective of this experimentation project was to assess proposed technology and process capability within the operational context of sufficient fidelity and variety to justify the cost and effort of integrating these capabilities within the iteration Spiral-X MDA system (*see Figure 44*).

Like the other two linked projects (*see report sections II:A:14 and II:C:7:a*), analysis milestones (*see Table 7*) were defined by the lead researcher, and clustered in three distinct phases to align with the concurrent research effort:

Table 7. MDA Assessment analysis milestones and timeline

	TITLE	***TIMELINE***
PHASE 1:	Discovery	JAN – FEB 2008
PHASE 2:	Process reengineering for improved TTP	MAR – OCT 2008
PHASE 3:	Delivery, validation and feedback/review of proposed Spiral-*X* MDA	NOV 2008 – DEC 2009

Key tasks included:

- Oversight of an Interagency Operation Center (IOC) event, demonstration events in separate venues, and related MDA Spiral-1 specific data collection within Trident Warrior 08; ensuring that the events are designed to meet IOC, MDA program and technology vendor requirements
- Development and coordination of assessment objectives with subject matter experts and stakeholders, and develop community of interest for assessment
- Led development, with the participation of all stakeholders, of an integrated Data Collection and Assessment Plan (includes objectives, data requirements, metrics, roles and responsibilities)
- Data collection management from all applicable venues, with archiving and search capabilities to support multiple requests for information (RFIs) and analyses
- Produced a final report of results in collaboration with stakeholders and other assessment leads
- Coordinated with SPAWAR, technology stakeholders and Fleet representatives in preparation for DoD doctrine, organization, training, materiel, leadership and education, personnel and facilities (DOTMLPF)

recommendations for a Military Utility Assessment (MUA); then archived documentation, event results and associated data relevant to MDA Spiral-1

- Contributed to definition of Spiral-2 from Spiral-1 assessment and planning lessons learned

POC: Dr. Shelley Gallup (spgallup@nps.edu)

III. RESULTS

Since its founding in January 2004, the MDSRP has provided seed funding for new research programs, sponsored student travel and research, created a 1,200 person community of interest, created educational programs, and invested in at-sea experimentation programs. In FY10 over 25 students were directly supported in thesis, research, and field experimentation programs. Monthly interdisciplinary meetings are held with faculty, students, and off-campus participants, including Stanford Research Institute, local law enforcement, and regional FBI agents. Attendance at these meetings averages around 20 people each month. In FY11 the MDSRP directly funded three maritime security research events with Singapore and four other maritime programs. The community of interest is sent a monthly newsletter that shares community research programs, national calendar of events, and recent publications in the maritime defense and security field.

The MDSRP was funded with Navy mission funds, and therefore directly supported the NPS education mission. The original program memorandum funding the MDSRP expired in FY11. In January 2011, after considering several alternatives, NPS and NSI leadership decided to close down the MDSRP coordinating function while retaining the individual research programs that had independent sponsorship.

Maritime security remains a complex challenge requiring international, regional, interagency, and intergovernmental cooperation. Since the stand-up of the MDSRP in 2004, the U.S. has developed MDA strategies; created maritime transportation security plans; enhanced regional cooperation worldwide to combat maritime terrorism, piracy, and smuggling; and designated commands like USNORTHCOM to lead continuing national maritime security efforts. Although the MDSRP was officially decommissioned on 1 October 2011, individual NPS faculty and students will continue their efforts to secure the global maritime commons and better or national maritime security.

A. GOALS MET

In the first eight to fifteen months of the program all but one of the initial goals were met. The initial vulnerability assessment was completed, and the "AS IS" system architecture description was crafted and distributed on the federal level. An MDA needs and requirements document was created, which informed efforts to coordinate MDA research across the NPS campus and cross communicate within a developing community of interest. The Maritime Domain Protection Modeling and Gaming Laboratory was not completed due to a lack of independent sponsorship. However, the MDSRP did support maritime domain protection modeling, analysis, and gaming throughout its operational lifetime.

The midterm program goals to be addressed in the first three years were all met, some earlier than anticipated. A proposed *National Maritime Domain Protection Architecture* articulating CONOPS and command structure was drafted, and then tested in an interagency/joint war game. A database for classified interagency reference was created and has been maintained. Port infrastructure analysis in relation to support of U.S. force projection was completed through a variety of independent faculty research efforts, NPS student theses, and red celling activities. The resulting Center for Infrastructure Defense (CID) is one of the many programs given MDSRP seed money that will continue on past close of the MDSRP (*see report section II:A:14 for program details*). Data mining and fusion techniques and systems based on requirements generation were demonstrated and applied across the DoD.

The long term program goals were also met. Based on initial MDA architecture analysis, the national MDA CONOPS is being implemented. Although no physical structure was built, ongoing MDSRP red cell activities fulfilled the requirement to test Unified Command Maritime CONOPS. The CID, as mentioned earlier, continues to provide complete and updated port infrastructure analysis in relation to support of U.S. force projection. Research is still in progress to develop automatic data mining and fusion systems for multi-level security access through GSEAS and DISE (*see report section II:C:6 for program details*). Efforts to evaluate alternative platform capabilities for MDA

are also still ongoing through the SEA projects (*see report section II:A:1:a for program details*).

B. PROJECT MATURATION

As intended from the start, many projects seeded with MDSRP funds have matured and are now independently funded, so will continue past the close of the MDSRP. A representative sample of these mature programs are summarized in Table 8.

Table 8. Representative sample of mature programs seeded with MDSRP funds

PROGRAM	**TITLE**	**See report section:**
MIST	*Multimodal Information Sharing Team*	II:A:17
Seaweb	*Subsurface Acoustic Sensor Network*	II:C:5
HFN	*Hastily Formed Networks*	II:C:3
FIST	*Field Information Support Team*	II:C:2
GSEAS MDA	*NPS Graduate School of Engineering and Applied Sciences MDA Team*	II:A:1:a
SEA Projects	*Systems Engineering Analysis student projects*	*Detailed in various places throughout this report*

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APPENDIX A: SELECTED PUBLICATIONS (FACULTY AND PARTNERSHIPS)

Bachmann, R.J. and F. Boria, P. Ifju, R. Quinn, J. Kline, R. Vaidyanathan (2005). "Utility of a Sensor Platform Capable of Aerial and Terrestrial Locomotion," *International Conference on Advanced Intelligent Mechatronics*, Monterey CA, July 2005

Brown, G. and M. Carlyle, A. Abdul-Ghaffar, J. Kline (2008). "A Defender-Attacker Optimization of Port Radar Surveillance," *Naval Research Logistics,* 58(3), pp. 223-235

Brown, G. and J. Kline, R. Rosenthal, A.R. Washburn (2007). "Steaming on Convex Hulls," *Interfaces* v37n4 2007, pp. 342-352

Brown, G. and W. M.W. Carlyle, D. Diehl, J. Kline, K.R. Wood (2005). "A Two-Sided Optimization for Theater Ballistic Missile Defense," Operations Research v53n5 Sept/Oct 2005, pp. 745-763.

Davidson, K. L., Frederickson, P.A., and T. V. Huynh: 2009, "NPS System-of-Systems Exploitation of Knowledge of Atmospheric and Ocean Surface Impacts for MIO and Maritime Security", White Paper prepared for Commander, Navy Meteorology and Oceanography Command (CNMOC), v9, February 2009

Gaver, D. P., Jacobs, P. A. and Sato, H. "Assessing resource requirements for maritime domain awareness and protection (security)," *International Journal of Performability Engineering,* v5:n1 January 2009, pp.85-98.

Gaver, D. P., Jacobs, P. A., and Glazebrook, K. D. "Search for a malevolent needle in a benign haystack," Chapter 6 in *Game Theoretic Risk Analysis of Security Threats* (eds. Bier, V. M. and Azaiez, M. N.) *International Series in Operations Research and Management Science,* Vol. 128, Springer, New York, 2009.

Grimmett, D. and J. Rice (2008). *Seaweb Long Beach Test Plan*, February 2008

Grimmett, D. J. and B. Marn, C. L. Fletcher, R. K. Creber, J. A. Rice (2008). "Planning Considerations for the Physical Topology of Undersea Acoustic Communications Networks," *Proc. MILCOM*, San Diego, CA, November 17-19, 2008

Honegger, B. (2011). "NPS Pioneers Seaweb Underwater Sensor Network," *Undersea Warfare Magazine*, pp. 20-23, Summer 2011

Jenkins, W. F. and J. A. Rice, L. J. Ziomek, M. D. Green (2010). "Multi-Channel MFSK Modulation and Demodulation through Short-Range, Large-Bandwidth, Underwater Acoustic Channels," *Proc. European Conference on Underwater*

Acoustics (ECUA), Istanbul, Turkey, July 5-9, 2010

Kapolka, D. and J. K. Wilson, J. A. Rice, P. Hursky (2008). "Equivalence of the waveguide invariant and two path ray theory methods for range prediction based on Lloyd's mirror patterns," *Proc. of Meetings on Acoustics (POMA)*, June 2008

Kline, J. (2010). "Maritime Security," *Securing Freedom in the Global Commons*, edited by Scott Jasper, Stanford Press, 2010.

Ramp, S., Rice, J., Stacey, M., Garfield, T., Largier, J., "SF Bayweb 2009: Planting the Seeds of an Observing System in the San Francisco Bay," MTS/IEEE Oceans Conference, Biloxi, MS, 26-29 October 2009.

Rice, J. (2009). "MDA Proposal Vignettes for Consideration by NORTHCOM," five proposals submitted to USNORTHCOM, January 29, 2009

Rice, J. and M. D. Green (2008). "Underwater Acoustic Communications and Networks for the US Navy's Seaweb Program," *Proc. Second International Conference on Sensor Technologies and Applications (SENSORCOMM)*, Under Water Sensors and Systems Track, Cap Esterel, France, August 25-31, 2008

Rice, J. and M. D. Green (2008). "Advances in Acoustic Communications and Undersea Networks," *Proc. Maritime Systems & Technology (MAST)*, Cadiz, Spain, November 12-14, 2008

Rice, J. and D. Grimmett (2009). *San Francisco Bayweb 2009 Test Plan*, April 2009

Rice, J. and C. W. Ong (2010). "A Discovery Process for Initializing Underwater Acoustic Networks," *Proc. Fourth International Conference on Sensor Technologies and Applications (SENSORCOMM)*, Mestre, Italy, July 18-25, 2010

Rice, J. and G. Wilson, M. Barlett, J. Smith, T. Chen, C. Fletcher, B. Creber, Z, Rasheed, G. Taylor, N. Haering (2010). "Maritime Surveillance in the Intracoastal Waterway using Networked Underwater Acoustic Sensors integrated with a Regional Command Center," *Proc. 2nd International Conf. on WaterSide Security*, Marina di Carrara, Italy, November 3-5, 2010

Rice, J. and J. Kalscheuer (2011). "A Selective Automatic Repeat Request Protocol for Through-Water Acoustic Links," *Proc. 4th International Conference on Underwater Acoustic Measurements*, Kos, Greece, June 20-24, 2011

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Salem, A. and W. Walsh, L. Englehorn (2010). "Industry and Public Sector Cooperation for Information Sharing: Port of Honolulu", *NPS Report*, January 2010

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Salem, A. and W. Walsh, O. Doherty (2008). Doherty, Owen, "Industry and Public Sector Cooperation for Information Sharing: Ports of Long Beach and Los Angles", *NPS Report*, September 2008

Salmeron, J. and J. Kline, S.G. Densham (2011). "Optimizing Schedules for Maritime Humanitarian Cooperative Engagements for a United States Navy Sea Base," *Interfaces*, v41 n3, 2011: pp. 238-253

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APPENDIX B: SELECTED PRESENTATIONS

Blue, P. M. and C. L. Fletcher, J. A. Rice (2009). "Simulation of Seaweb Link and Network Layers using OPNET," *Proc. TTCP TP-9 ASW Systems & Technologies Panel Annual Meeting*, Dartmouth, Nova Scotia, Canada, September 21-25, 2009

Davidson, K. and T. Huynh (2008) "Field Tests of Coastal Surveillance 'System of Systems', *6th NPS/TDS/LLNL Security Workshop on Globalization& Maritime Security,* Marriott Crystal Gateway Hotel, Crystal City, VA 20-12 July 2008

Kelton, D., Brown, G., Kline, J. and Pidgeon, E. (2008). "Modeling the Effects of a Transportation Security Incident upon the Marine Transportation System," presented to Mr. Owen Doherty, Director of Maritime Security, Department of Transportation Washington, DC, 8 December 2008

Kline, J. (2009). *"Securing the Maritime Global Commons"* presentation to the *U.S. Mission to the United Nations*, Geneva, Switzerland, 22 September 2009

Kline, J. (2009). "*Piracy and Maritime Security*", presentation to the *World Affairs Council,* San Francisco, 18 November 2009

Gaver, D. P., Jacobs, P. A., Alderson, D. and Chng, K. C. (2007). "Domain Protection Methodologies," Invited presentation, *INFORMS,* Seattle WA, November 2007

Gaver, D. P., Jacobs, P. A., Kress, M. and Glazebrook, K. D. (2006). "Search for a malevolent needle in a benign haystack," Invited presentation, *INFORMS*, Pittsburgh PA, 5-8 Nov. 2006

Gaver, D. P. and P. A. Jacobs. and H. Sato (2005). "A maritime domain awareness and protection problem," Invited presentation, *INFORMS*, San Francisco, November 2005

LeFever, B. (2009). "Evaluation of the maritime operational threat response forces for the Pacific Coast theater,*"* finalist *MORS Tisdale Competition*, March 2009

LeFever, B. (2009). *"*Evaluation of the maritime operational threat response forces for the Pacific Coast theater*",* OSD (Homeland Defense and National Security Affairs), March 2009

LeFever, B. (2009). "Evaluation of the maritime operational threat response forces for the Pacific Coast theater*",* DOT Maritime Security. March 2009

Lefever, B. (2008). "Evaluation of the Maritime Operational Threat Response Force for the Pacific Theater," presented to Mr. Allen Miller and staff, Under Secretary of

Defense for Homeland Defense and America Security Affairs, Washington, D.C. 8 December 2008

Ramp, S., Rice, J., Stacey, M., Williams, M., Largier, J., Garfield, T., Bahr, F., (2009). "SF Bayweb 2009, Planting the Seeds of a new Observing System in the San Francisco Bay," *Eastern Pacific Ocean Conference*, Victoria, BC, Canada, 23-26 September 2009.

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APPENDIX E: REPRESENTATIVE PARTNERSHIPS

This is a representative listing provided to demonstrate program breadth and reach, and is not intended to be inclusive of all agencies and organizations that were involved with the MDSRP at some point during its program lifetime.

ACADEMIA AND INDUSTRY PARTNERS:

California State University, Monterey Bay
Cisco Systems
CyberDefense Systems
INTER-4
Lawrence Livermore National Laboratory (LLNL)
Mercury Data Systems
Monterey Bay Aquarium Research Institute (MBARI)
Monterey Institute for International Studies (MIIS), Middlebury College
Panetta Institute for Public Policy
Port Security CSR
Rajant Corporation
RAPIER
Redline Communications
San Francisco State University (SFSU)
Sensor Island
Stanford Research Institute (SRI) International
Stevens Institute for Systems Engineering
Temasek Labs
University of California, Berkeley (UC Berkeley)
University of California, Davis (UC Davis)
University of California, Santa Barbara (UCSB)

U.S. GOVERNMENT PARTNERSHIPS:

Chief of Naval Operations (OPNAV)
Commander U.S. Pacific Fleet (COMPACFLT)
Commander Logistics Group, Western Pacific (COMLOG WESTPAC)
Defense Intelligence Agency (DIA)
U.S. Department of Energy (DOE)
U.S. Department of Homeland Security (DHS)
U.S. Department of Justice (DOJ)
U.S. Department of State (DOS)
U.S. Department of Transportation - Maritime Administration (DOT-MARAD)
Fleet Numerical Meteorology and Oceanography Center (FNMOC)

Joint Chiefs of Staff
Joint Special Operations Command (JSOC)
Marina Police Department
Maritime Liaison Office (MARLO)
National MDA Coordination Office (NMCO) *formerly OGMSA*
National Maritime Intelligence Center (NMIC)
National Nuclear Security Administration (NNSA)
National Reconnaissance Office (NRO)
National Security Administration (NSA)
Navy Tactical Exploitation of National Capabilities Program (TENCAP)
Naval Network Warfare Command (NETWARCOM)
Office of the Director of National Intelligence (ODNI)
Office of Naval Intelligence (ONI)
Office of Naval Research (ONR)
Office of the Secretary of Defense for Homeland Defense
Space and Naval Warfare Systems Command (SPAWAR)
U.S. Coast Guard (USCG)
U.S. Joint Forces Command (USJFCOM) *disestablished in August 2011*
U.S. Navy Forces North (NAVNORTH)
U.S. Northern Command (USNORTHCOM)
U.S. Pacific Command (USPACOM)
U.S. Special Operations Command (USSOCOM)
U.S. Southern Command (USSOUTHCOM)

INTERNATIONAL PARTNERSHIPS:

DSO National Laboratories, Singapore
Singapore Ministry of Defence (MINDEF)
Nanyang Technical University (NTU)
Royal Thai Air Force (RTAF)
Royal Thai Armed Forces (RTArF)
Royal Thai Army (RTA)
The National University of Singapore (NUS)
Singapore's Defense Science and Technology Agency (DSTA)
Temasek Defence Systems Institute (TDSI)

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   Washington D.C.

4. Director, Center for Homeland Defense and Security
   Naval Postgraduate School
   Monterey, California

5. Director, National Security Institute
   Naval Postgraduate School
   Monterey, California

6. Dean, Graduate School of Operations and Information Science
   Naval Postgraduate School
   Monterey, California